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Introduction of the Continuous Emission Monitoring System at the Thermal Power Plants of Hrvatska elektroprivreda

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Summary:

An overview of Croatian legislation in the field of air protection is given in this paper with special attention to Decree on stationary sources emission limit values. The owner's obligations concerning first, occasional and continuous emission measurements are described, especially these of Hrvatska elektroprivreda (HEP) as the present owner of all thermal power plants in Croatia. The attention is drawn to HEP's activities on conducting of the emission measurement program, which has the introduction of Continuos Emission Monitoring System (CEM) as its final purpose.

1. INTRODUCTION

Realizing obligation of so called first, occasional and continious emission measurement for owners of stationary sources is directed by the "*By-Law on Limit Values of Pollutant Emissions from Stationary Sources into the Air*" (Official Gazette of Croatia 140/97). In order to realize mentioned obligations, HEP (Croatian Electricity Network), as owner of all thermal power plants in Croatia, has started with complete and systematic conducting of the first measurements. During 1998 and at the beginning of 1999 measurements on all furnaces and gas-turbines in seven thermal power plants has been realized.

The next HEP activity, that follows from the obligations to the Law, is Continious Emission Monitoring (CEM) system establishing not later than February 1, 2000. With a view to successfull realizing of preparing activities for establishing the CEM system, EKONERG - Energy Research and Environmental Protection Institute Ltd. has made a dissertation "Techniques of Continious Emission Monitoring at Thermal Power Plants". In addition to this dissertation different ways of establishing the CEM system has been analized, considering the possible measurement approach and realization. On the basis of standard configuration preliminated offers of some manufacturers there has been made the first evaluation of all investments for each analized variant. This article represents short review of the disertation, with the accent on performances of all thermal power plants and the number of possible sollutions that follow from the Law.

2. REGULATIONS IN CROATIA

2.1. GENERALLY ABOUT AIR QUALITY PROTECTION

On the fig. 1 is a simplified shematic review of the air quality protection regulation. In Croatia there are following legal acts that refer to air quality protection problems:

- Law on Environmental Protection, NN (Official Gazette) 82/94
- Law on Air Quality Protection, (NN 48/95)
- Rule Book on Environmental Emission Inventory, (NN 36/96)
- By-Law on Recommended and Limit Air Quality Values, (NN 101/96, 2/97)
- By-Law on Environmental Impact Assessment, (NN 34/97, 37/97)
- By-Law on Limit Values of Pollutant Emissions from Stationary Sources into the Air, (NN 140/97).
- By-Law on Substances Depleting the Ozone Layer (NN 7/99)

Together with the "*Law on Air Protection*" the most important instruments for realizing the air protection policy are two by-laws: "*By-Law on recommended and Limit Air Quality Values*" and "*By-Law on Limit Values of Pollutant Emissions from Stationary Sources into the Air* ", where, in the emission measuring context, By-Law on limit values is more important.

2.2. BY-LAW ON LIMIT VALUES OF POLLUTANT EMISSIONS FROM STATIONARY SOURCES INTO THE AIR

This by-law directs limit values of pollutant emissions from stationary sources into the air (GVE), obligations and requests that are made in front of the stationary source owner with regard to monitoring emissions, and penal rules. Stationary sources are industrial plants, technological processes, and objects from which pollutant substances are emitted into the atmosphere. In the thermal power plants emission context it is a question of furnaces and gas-turbines. The classification of furnaces, according to the article 73 of the By-Law, is given in table 1.

Table 1. Classification of furnaces according to type of fuel and thermal power (fuel heat)

FURNACE	SOLID FUEL	LIQUID AND GAS FUEL
Very small	< 0,1 MJ/s	< 0,1 MJ/s
Small	0,1 - 1 MJ/s	0,1 - 5 MJ/s
Medium	1 - 50 MJ/s	5 - 50 MJ/s
Large	> 50 MJ/s	> 50 MJ/s

The obligations of emission measurement are defined by conducting of the first, occasional, continious and special measurement. The conducting of the first measurement is obligation for all furnaces and gas turbines. Establishing of the CEM system is obligation for medium furnaces, all large furnaces, as well as, gas-turbines with thermal power more than 50MJ/s.

The CEM's measuring scope for furnaces is directed by the articles 85 and 86. Medium furnaces on solid and liquid fuels with thermal power more than 25 MJ/s, have to be equipped with the measurement systems for continious measurement of flue gases opacity (smoke number). Large furnaces that use solid or liquid fuel require continious emission measurement of NO_x, CO, SO_2 and solid particles (as well as relevant parameters such as oxygen contents and flue gases temperature). Gas fired large furnaces require continious emission measurement of NO_x, CO and opacity. If nitrogen oxides have less than 10% of NO_2, than measurement of NO_2 is not required.

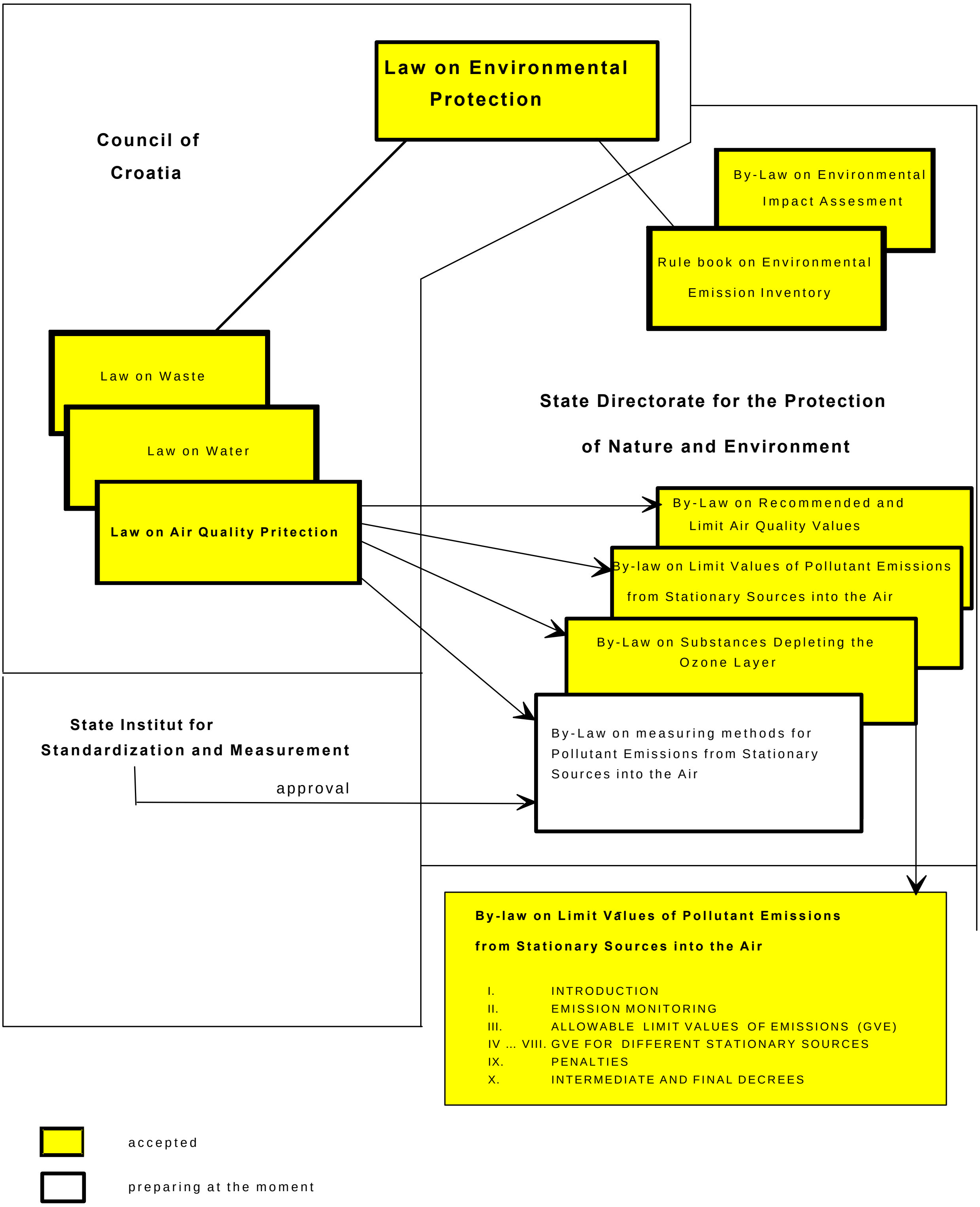


Figure 1: Development of croatian regulation in the field of the air quallity protection

Gas-turbines (fuel heat > 50 MJ/s) require system establishing for continious emission measurement of CO, SO_2, NO_2 and opacity (also oxygen contents and flue gases temperatures). In the case of natural gas firing measurement of SO_2 is not required.

The continious measurement scope is obligated for each unit (furnace or gas-turbine) separately. However, if there are more furnaces connected to the common stack, it is allowed to install only one CEM system that is common for all furnaces (article 87). In that case it is necessary to determine each emission from each furnace by calculation or by occasional measurements. In the case of determining by calculation it is necessary to make the measurements at least one`s a year. In this way we achieve a saving at establishing the CEM system that is very important in plants with more production units (as it is the case in cogeneration plants TE-TO Zagreb and EL-TO Zagreb).

By the article 128, continious pollutant emission measurement from stationary sources (existing or under construction) should start not later than February 1, 2000.

According to continious emission monitoring every half an hour will be created an average from the measuring datas. These averages will be stored as frequency distribution. The frequency distribution will be determined after the ending of calender year. From the half an hour average values a daily average will be calculated regarding to realized daily working hours.

By the article 14 of the By-Law limit values (GVE) will be satisfied if, on the basis of continious measurements in the calender year:

- all the average 24-hour values are less than GVE,
- 97% of half an hour average values is less than 1,2 GVE,
- all half an hour average values are less than double GVE

By the article 5 of the By-Law, pollutant emission measurement in flue gases from stationary sources should be realized according to Croatian norms and/or methods that give mutually comparable results.

3. STANDARDIZATION IN CROATIA

The first Croatian norms are published in March 1996. The Law on Standardization (NN 55/96) and Rule Book on Croatian Norms (NN 74/97) are also published that year. By this Rule Book it is determined the way of accepting the foreign norms in original.

To prepare Croatian norms the State Institute for Standardization and Measurement establishes technical committees that creat national concensus of all the subjects that are interested in particular standardization field. These published new Croatian norms are made in great deal on the bases of already existing international and european norms. The norm collection becomes renewed by the acceptance of new norms and by the retreat of the old ones, and unsuitable technical practice ia abandoned and substituted with the new one that is technically coordinated with practice in Europe and the world.

3.1. NORMS AND GUIDELINES FROM THE EMISSION MONITORING FIELD

By the action of Technical Board TO 146 (The air quality) in Croatia are published norms mentioned in table 2. The question is about the first norms publications made by taking over.

Table 2. Croatian Norms (Air Quality)

HRN ISO 4225:1997	*Air Quality – Dictionary (ISO 4225:1994)*
HRN ISO 4226:1997	Air Quality – Measuring units (ISO 4226:1993)
HRN ISO 7934:1997	Stationary source emissions – Determination of the mass concentration of sulfur dioxide – Hydro peroxide/barium perchlorate/Thorin method (ISO 7934:1989)
HRN ISO 7935:1997	Stationary source emissions – Determination of mass concentration of sulfur dioxide – Performance characteristic of automated measuring methods (ISO 7935:1992)
HRN ISO 9096:1997	Stationary source emissions – Determination of concentration and mass flow rate of particulate material in gas-carrying ducts – Manual gravimetric method (ISO 9096:1992)
HRN ISO 10155:1997	Stationary source emissions – Automated monitoring of mass concentrations of particles – Performance characteristic, test methods and specifications (ISO 10155:1995)
HRN ISO 10396:1997	Stationary source emissions - Sampling for the automated determination of gas concentrations (ISO 10396:1993)
HRN ISO 10780:1997	Stationary source emissions – Measurement of velocity and volume flowrate of gas streams in ducts (ISO 10780:1994)

In March 1998 The State Directorate for the Protection of Nature and Environment (DUZPO) suggested an application of some norms and VDI guidelines regarding to implementation of emission measurement. These guidelines will be applicated until the finishing of the By-Law on Monitoring Methods of Pollutant Emission from Stationary Sources into the Air.

4. THE THERMAL POWER PLANTS OBLIGATIONS REGARDING TO THE EMISSION MEASUREMENT

4.1. THE SHORT REVIEW OF HEP THERMAL POWER PLANTS

HEP owns seven thermal power plants that are used for electrical energy and heat production. There are 32 installed stationary sources (without auxiliary boilers and units under construction). The steam boiler K1 (steam production of 50 t/h) in EL-TO Zagreb is out of operation for quite a long time, so we can say that at this moment there are 31 production units, 18 steam boilers, 7 water boilers and 6 gas-turbines. All these boilers, except the steamblock boilers in TE-TO Osijek (3 x 18 t/h; 3 x 14 MJ/s), belong to large furnaces. In the table 3 there is a review of some basic characteristics of large furnaces and gas-turbines.

Table 3. Large furnaces and gas turbines at thermal power plants of HEP

PLANT	FUEL	NOMINAL LOAD	FUEL HEAT, MJ/s
CCPP Jertovec	Two stacks		
gas turbine PT1	natural gas / distillate oil	31,5 MW	123
gas turbine PT2	natural gas / destillate oil	31,5 MW	123
TPP Plomin 1	One stack		
steam boiler	coal	385 t/h (120 MW)	344
TPP Sisak	Two stacks		
Unit 1: boilers A and B	natural gas / heavy oil	2 x 335t/h (1 x 210 MW)	2 x 274
Unit 2: boilers A and B	natural gas / heavy oil	2 x 335t/h (1 x 210 MW)	2 x 274
EL-TO Zagreb	Four stacks		
Steam boilers:			
K1	natural gas / heavy oil	50 t/h	41
K2	natural gas / heavy oil	80 t/h	56
K3	natural gas / heavy oil	100 t/h	83
K4	natural gas / heavy oil	100 t/h	86
K5	natural gas / heavy oil	100 t/h	86
Water boilers:			
WK1	natural gas / heavy oil	58 MJ/s	63
WK2	natural gas / heavy oil	58 MJ/s	63
WK3	natural gas / heavy oil	116 MJ/s	129
gas turbine PTA1	natural gas	25 MW	91
gas turbine PTA2	natural gas	25 MW	91
TE-TO Zagreb	One stack		
Steam boilers:			
K1	natural gas / heavy oil	180 t/h	130
K3	natural gas / heavy oil	500 t/h	384
PK3	natural gas / heavy oil	80 t/h	58
Water boilers:			
VK3	natural gas / heavy oil	58 MJ/s	64
VK4	natural gas / heavy oil	58 MJ/s	64
VK5	natural gas / heavy oil	116 MJ/s	129
VK6	natural gas / heavy oil	116 MJ/s	129
TPP Rijeka	one stack		
steam boiler	heavy oil	1012 t/h (320 MW)	800
TE-TO Osijek	Three stacks		
boilers A and B	natural gas / heavy oil	2x125 t/h	2 x 98
gas turbine PT1	natural gas /distillate oil	25 MW	100
gas turbine PT2	natural gas /distillate oil	25 MW	100

CCPP Jertovec is used exclusively for electrical energy production. Its basic components are two gas-turbines (PT1 and PT2), two heat recovery boilers (K1 and K2) and two full condenzing steam turbines (TA1 and TA2). The heat of gas-turbine flue gases is used in boilers K1 and K2, where they produce the steam for steam turbines. These mentioned plants are connected to a block connection, and they make two COMBI units in following combinations:

- unit 1: PT1-K1-TA1
- unit 2: PT2-K2-TA2.

Characteristics given in table 3 refer to independent work of gas-turbines. Each turbine (unit) has its own stack.

TPP Plomin 1 is coal fired, 120 MW, thermal power plant, used exclusively for electrical energy production. The plant is in regular exploatation since 1970.

Stationary source in TPP Plomin 1 is one boiler that produces steam for steam turbine. The boiler plant is equipped with two electrostatic precipitators used to remove fly ash (solid particles) from flue gases. After separating solid particles, flue gases go to the atmosphere through a new 340 m high stack of TPP Plomin 2.

The boiler at TPP Plomin 1 has been projected for using local high sulphur bituminous coal from Raša coal mine. From the beginning of 90-s till today mixture of Raša and imported low-sulphur bituminous coal has been used as a fuel. Reconstruction of electrical filter during 1999 made firing only imported coal possible. In addition to this reconstruction, system for continious emission monitoring of solid particles has been built. Since it is only the part of the required measuring scope, it has not been considered in analysis.

At TPP Plomin 2, which construction is at the end, the CEM system has been built in measuring scope that completely satisfies by-law, so this unit has not been included by survey.

TPP Sisak has two identical full condensing unit (2 x 210 MW). Both units work for over 20 years. As on the both plants has been made revitalization, they should not stop working till 2015. Each unit has two identical boiler plants (steam boilers "A" and "B") and one stack common to the both boilers. Flue gases ducts of boilers A and B are not connected and enter separately into the stack.

EL-TO Zagreb is used for heat and electrical energy production. Heat is produced on two levels, where the mediums are hot water and superheated steam. Hot water is used for central and sanitary water heating, while the overheated steam is used in technological processes of industrial plants or for large objects heating.

For this purpose on the EL-TO Zagreb location has been built number of plants of direct process, that produce exclusively heat, and cogeneration plants, that beside heat produce also electrical energy. For direct process of heat production there has been installed three water boilers WK1, WK2 and WK3 and two low pressure steam boilers K1 and K2. The boiler K1 has not been used for a long time.

There are two cogeneration unit as follows:

- unit 1 that consists of one high pressure steam boiler with capacity of 100 t/h superheated steam (boiler K3) and back-pressure steam turbine of 11,5 MW nominal output.
- unit 2 that consists of two high pressure steam boilers with capacity of 100 t/h (boilers K4 and K5) and full condensing steam turbine (30 MW) .

Beside these mentioned units, at the end of 1998 gas-turbine plant, called "PTE Zagreb-west", began to work. It consists of two gas-turbines nominal electrical power of 25 MW and heat recovery boilers (2 x 51 MJ/s) for technological steam production and water heating.

At EL-TO Zagreb plant there are 4 stacks:

- two stacks of the PTE Zagreb-west plant (each for every unit)
- new 200 m high stack
- old 85 m high stack

Four flue gases ducts enter into the new stack (boiler K4, boiler K5, boiler K2 and common duct of boilers WK1, WK2 and K3). Boilers WK3, K1 and K3 (boiler K1 is not included in analyses) has connections with the old stack through underground duct. In the usual working regimes, flue gases from the boiler K3 go out through the new stack.

TE-TO Zagreb is also cogeneration plant. It is located on the left bank of river Sava, near the large electrical consumers and approximately centrally regarding to two groups of heat consumers: industrial technological steam consumers and hot water consumers.

Today there are three steam boilers at TE-TO Zagreb (K1, K3 and PK3 - boiler of block 2 is removed), four water boilers (VK3, VK4, VK5 and VK6) and steam turbines of units 1,2 and 3. Flue gases from all boilers go to the atmosphere through the common 200 m high stack. Water boilers are connected to the common flue gases duct that is used to dicharge the gases to the stack. Boilers PK3 and K1 also have common duct, while boiler K3 has a separate connection with the stack. There are three enters to the stack.

TE Rijeka (1 x 320 MW) is located on the sea shore southeast from the city of Rijeka. The basic components of the 320 MW unit are steam boiler of nominal output of 1012 t/h, and full condensing steam turbine. Today the plant exclusively uses heavy oil as fuel.

The system for continious SO_2 emission measurement has already been installed together with usual measurement of O_2 concentration and flue gases temperature. These systems include in-situ measurement. Electro-chemical cell with solid electrolyte - potassium sulfate - and with platinum electrodes (Westinghouse, model EC960) is used for SO_2 measurement.

TE-TO Osijek is used for production of electrical energy and heat (town heating and technological steam for industrial purposes). TE-TO Osijek contains of two gas-turbines (2 x 25 MW) with one heat recovery boiler (steam production of 56 t/h), three "steamblock" boilers (3 x 18 t/h), and 45 MW unit with two steam boilers (2 x 125 t/h). The establishing of CEM system at Steamblock boilers (< 25 MJ/s) is not required, and the emission measurements will be occasional. It follows that the CEM system at TE-TO Osijek should include two steam boilers (2 x 125 t/h), that are connected to the stack with the common duct, and two gas turbines where each of them has its own stack.

4.2. FIRST MEASUREMENTS

The first measurements are conducted by experts of EKONERG - Energy Research and Environmental Protection Institute Ltd. EKONERG has a long-term experience in emission monitoring, and has been the first Croatian institution operating in the field of environmental protection granted the ISO 9001 certificate.

According to the planned integrated measuring program, 60 measurements in 25 boiler plants and six gas turbine plants were to be conducted. So far, 50 measurements have been conducted encompassing all thermal power plants, and the final reports prepared and submitted to the relevant county authorities. When the remaining monitorings shall be conducted depends on availability of individual units and fuel types.

The methods specified by ISO and DIN have been applied along with the VDI Guidelines recommended by the Croatian State Directorate for the Protection of Nature and Environment. With respect to the unit size and type of fired fuel, the monitoring included determination of:

- solid particles mass concentration,
- opacity,
- heat losses,
- mass concentrations of gaseous pollutants: carbon oxide (CO), nitrogen oxides expressed as NO_2 (NO_x as NO_2) sulphur oxides expressed as SO_2,
- mass concentrations of gaseous anorganic compounds of chlorine expressed as HCl and gaseous anorganic compounds of fluorine expressed as HF,
- mass concentrations of anorganic substances and their compounds (As, Pb, Cd, Cr, Co, Ni - total).

The analyses of emissions from typical thermal power plants focus on emission of solid particles, sulphur oxides (SO_2) and nitrogen oxides (NO_x), and their importance primarily depends on the type of fuel (gaseous, liquid or solid). When the gaseous fuel is fired under stationary operating conditions, the priority concern are NO_x emissions, while for plants firing liquid or solid fuel the priority is given to emission of solid particles and SO_2. The monitored values in the Croatian Power Board facilities confirm this approach although, in most cases, the SO_2 and NO_x emissions do not exceed currently stipulated limits, regardless of the fired fuel. The allowable limit values for existing large furnaces are given in the table 4.

Table 4: Limit values of pollutant emissions from existing large furnaces

Fuel:	solid	liqiud	gas
Ref. O_2 , %	6	3	3
Solid paritcles, mg/m$^{3\ *}$	200	100	10
Opacity	2 ^{o}R	2 ^{o}B heavy oil 1 ^{o}B others	1 ^{o}B
NO_x as NO_2 , mg/m$^{3\ *}$	1200	900	700
CO, mg/m$^{3\ *}$	250	175	100
SO_2 , mg/m$^{3\ *}$	6000 (until 1.1.2000.) 2000 (after 1.1.2000.)	5100 (until 1.7.2002.) 1700 (after 1.7.2002.	-

(* based on dry flue gases and 273,15 K ; 101,325 kPa)

The measuring results indicate that NO_x emissions during maximum loadings are just slightly higher than or at the emission limit levels. Concerning SO_2 emissions, currently thermal power plants in Croatia fire heavy fuel oil with sulphur content of 2 to 2.5%, which corresponds to the emission below the limit values. On the other hand, the solid particles emission from some of the units firing heavy fuel oil are in excess of allowable emission limit.

In the Plomin 1, coal fired Thermal Power Plant, the measured emission of solid particles also was above the limit. However, during 1999. the reconstruction of electrostatic precipitators has been made and present particle emmision from TPP Plomin1 is below the limit values. The new electrostatic precipitator plant allows firing 100 % of imported low-sulphur coal.

The obvious difference in environmental performance of individual types of fuels, in addition to the effect they have on reduction of thermal power plant maintenance costs, is one of the primary reasons behind the HEP intention to increase share of gaseous fuels in total fuel consumption of the thermal power plants wherever possible considering their availability and prices.

TE-TO Zagreb and EL-TO Zagreb Cogeneration Plants could be used as examples. They shall be fitted with new combined-cycle units firing only natural gas, thus replacing some of the existing capacities and increasing share of gas in total fuel consumption. The gas-turbine is already in trial operation in the EL-TO Zagreb (“PTE Zagreb-west”), while the erection works and installation of the new TE-TO Zagreb unit should start soon.

It should be noted that more stringent criteria now apply to the emission limits for the new plants. After July 1, 2004 (for SO_2 even earlier), uniform stricter criteria shall apply to all the thermal power plants. This means that without use of quality fuel or adequate protective measures (precipitators and desulphurization) it will be impossible to satisfy the regulations on particle and SO_2 emissions. Reduction in NO_x emissions will demand application of adequate protective measures (primary in the furnaces or secondary as removal of NO_x compounds from the fuel gases).

5. MEASURING SCOPE OF CEM SYSTEM

The CEM system should include emission monitoring from 22 furnaces and 6 gas turbines. Number of possible combinations and characteristics of each thermal power plant (from which also follows the number of necessary CEM systems) creates need for analyzing every thermal power plant, especially these which have installed several furnaces. Some different sollutions have been discussed, in the context of this survey, primarily in order to estimate total capital costs.

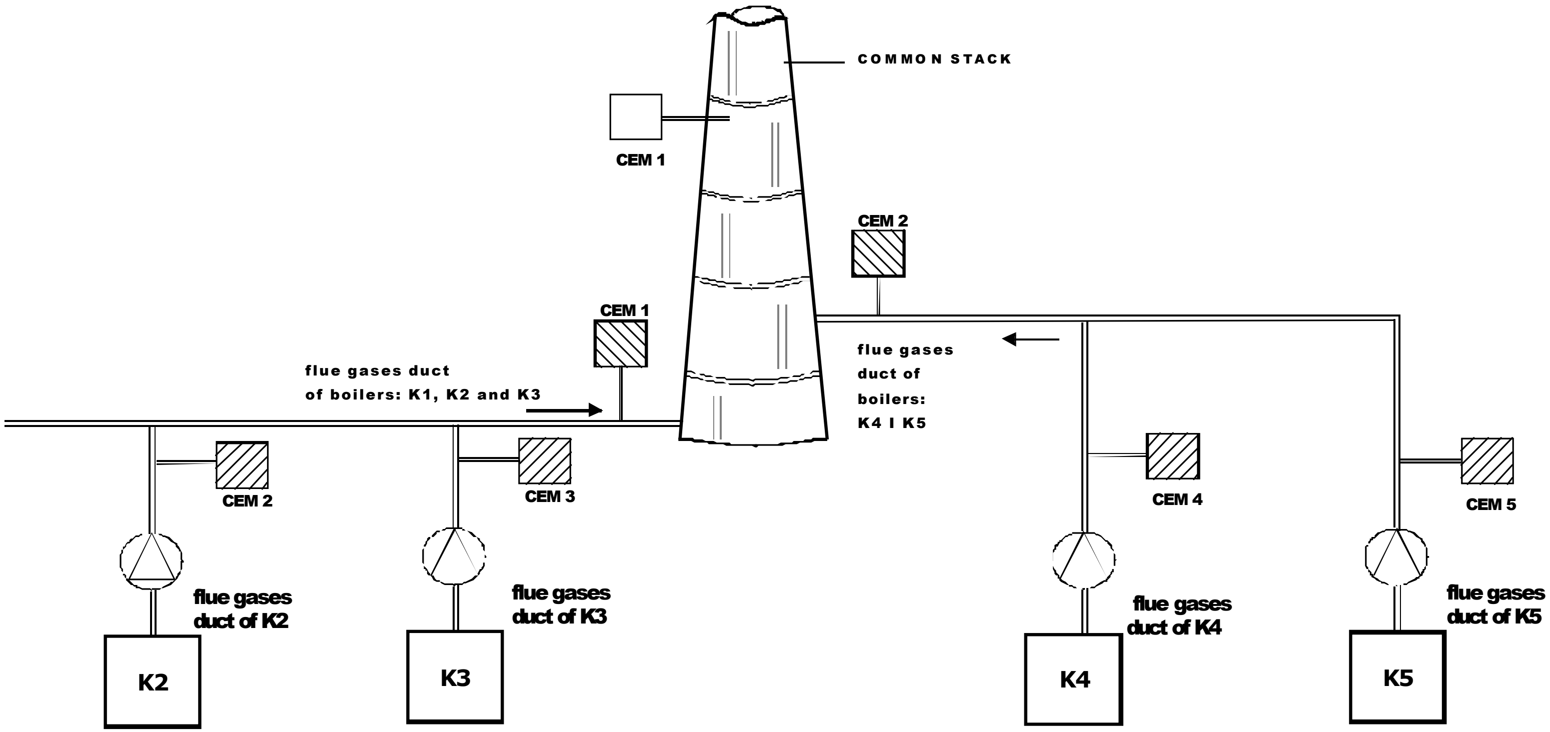
Three approaches have been applied to define different variants:

1. “one CEM system per stack”
2. “one CEM system per duct entering into the stack”
3. “one CEM system per each source”.

The basic differences of discussed approaches are schematically shown in fig. 2.

All three approaches include continuous total emission monitoring and completely satisfy by the regulation requests regarding to the obligation of establishing the CEM system. In some thermal power plants, depending on the number of furnaces, some variants are identical no matter of applied approach, (for example, TPP Rijeka and TPP Plomin 1).

In the case of the application of simple approach No. "1" the number of necessary systems would be suitable with the number of stacks from thermal power plants (that is also the minimal number of systems), and by that the investments would considerably decrease compared to other approaches. As it was mentioned before, this kind of approach is possible by the article 87 of the By-Law by which the emissions can be measured with common CEM system for several furnaces.



CEM system per stack"	total: 1 system	☐
CEM system per duct entering to the stack"	total: 2 systems	▧
CEM system per each source"	total: 5 systems	▨

Figure 2: Different approaches of CEMs application at TPPs of HEP

However, approach "1" in some cases can result with difficult calibration and changing of flue gases properties (which is very important at solid particles emission measurement by the direct "in-situ" methods). That could have negative influence on measuring accuracy, so it must be taken into consideration in the process of determining installation site (in-situ methods) or flue gases sampling location (extractive methods). The mentioned disadvantage is very important in the case of several furnaces with different characteristics, connected to the common stack.

Introducing the CEM system in this way would make total plant emission monitoring possible, but the emission share from separate sources would be unknown. The exceptions are gas-turbines because each of them has its own stack, as well as, TPP Rijeka and TPP Plomin 1 where there is only one source. Shares of individual sources in total emission (in other cases) would be determined by accounting (on the bases of balances and/or experimental emission factors) and occasional measurements. Independently of the way of determining some shares, by the article 87 of the By-Law, occasional measurements (for each furnace separately) should be conducted at least once a year.

Application of approach “2” would decrease occasional measurement obligations. In some cases, calibration procedure would become easier and impact of changing flue gases properties would become less important.

The approach "3" makes possible, on the other hand, not just the continious measurement of total emission, but also individual emissions from all furnaces. However, this sollution requires the maximum number of CEM systems, and also maximum investments.

The measuring scope in HEP’s thermal power plants and also the number of CEM systems (depending on applied approach) is given in table 5. Except the values given in the table all systems will include measurement of oxygen concentration and the flue gases temperature. Possible measurement of other relevant values has not been considered in these analizes.

Table 5. Measuring scope of CEM systems at thermal power plants of HEP

Plant	**Measuring scope**	**NUMBER OF CEM SYSTEMS**		
		Approach		
		1	**2**	**3**
CCPP Jertovec PT1, PT2	NO_x, SO_x, CO, opacity	2	2	2
TPP Plomin 1 steam boiler	NO_x, SO_x, CO, particles	1	1	1
TPP Sisak K1A, K1B, K2A i K2B	NO_x, SO_x, CO, particles	2	4	4
EL-TO Zagreb boilers gas turbines	 NO_x, SO_x, CO, particles NO_x, CO, opacity	 2 2	 5 2	 7 2
TE-TO Zagreb boilers	NO_x, SO_x, CO, particles	1	3	7
TPP Rijeka steam boiler	NO_x, SO_x, CO, particles	1	1	1
TPP Osijek Boiler A and B gas turbines	 NO_x, SO_x, CO, particles NO_x, SO_x, CO, opacity	 1 2	 1 2	 2 2
TOTAL:		**14**	**21**	**28**

6. EVALUATION OF NECESSARY INVESTMENTS

Analysis of total investments includes, beside different approaches, different applied measuring methods: in-situ (direct methods – index "D") or extractive methods – index "E". In-situ systems have been analized for measurement of solid particles emission and opacity, while both methods have been analized for gaseous pollutants emission measurement. The analysis also includes the assumption of one common sales company for all HEP's TPPs that would decrease total costs, especially necessary investments and maintenance costs.

The data, that has been used, are based on the offers from different manufacturers (Siemens, Horiba, Hartmann & Braun, Sick and Durag). These offers include standard configurations of measuring systems. As it was already mentioned, 6 variants have been analized (depending on chosen approach and measuring method) and each of them includes the following CEM system:

- measurement of solid particles emission and opacity by the photometric in-situ method
- mesurement of gaseous pollutant emission by extractive NDIR method or by in-situ method based on absorption of IR and UV radiation
- measurement of oxygen contents by electro-chemical method or by paramagnetic method.
- non-explosive atmosphere conditions
- without NO_2/NO_x converter
- all necessary hardware and software components for evaluation and assesment of measuring data

Depending on analized offer, total price of one CEM system with extractive gaseous pollutant emission measurement is 140.000 - 150.000 DEM (for the purpose of evaluation of total investments it is adopted 140.000 DEM). The CEM systems with in-situ measurement of gaseous pollutant are more expensive, 10 to 20 % in relation to extractive systems (it is necessary to point out that bigger investments are later compensated by smaller maintenance costs which has not been taken into account in this evaluation). For the purpose of analyses it has been adopted one price of CEM system with in-situ measurement for all measuring scope of 168.000 DEM.

These mentioned prices of CEM systems include spare parts for some time, following documentation, packing and transport expanses, custom and preparing the system on thermal power plant location. The price does not include installation works costs and personal training costs.

Although the differences in prices of some offers for complete CEM systems of the same type are quite small (10 %), differences in prices for sub-systems in some cases are bigger. Reasons for that are not the advantages of technical characteristics that would eliminate or point out some offers, but, first of all, different auxiliary equipment (which is not separately specified) and delivery of some components from other manufacturers (if the producing program of the offer does not include complete measuring scope). All this will not be examined in this survey because of the adopted assumption of one common delivery for the whole system.

The estimated values of total investment for all variants are given in fig. 3. The range of total investments is approximately from 1,9 to 4,4 million DEM. It is necessary to point out , one more time, that this was first evaluation based on mentioned assumptions and realized in given conditions. The whole line of factors will influence on the final select of CEM's conception, as well as, on the final total investment.

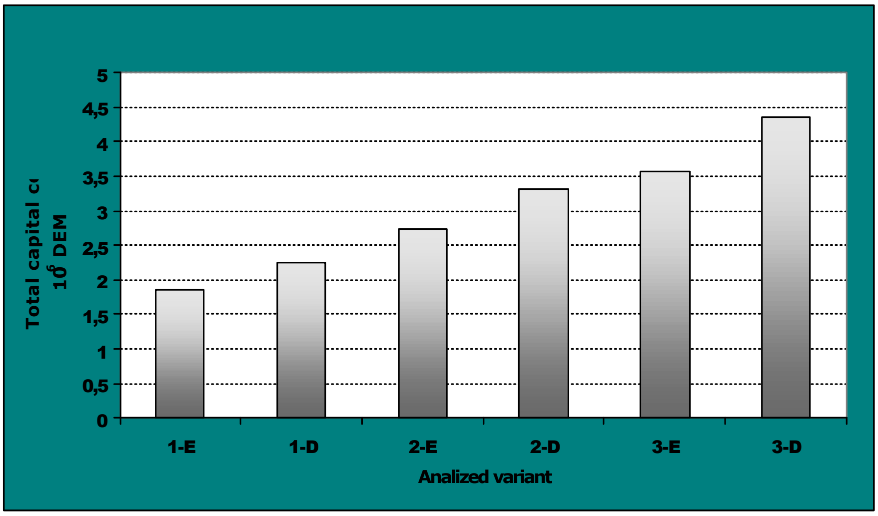


Figure 3. Total investment of HEPs CEM systems

7. CONCLUSION

CEM's scope for all HEP's thermal power plants is defined by the analysis of requests that follow from the "*By-Law on Limit Values of Pollutant Emissions from Stationary Sources into the Air* ". At boiler plants plants is necessary to install continuous measurement of gaseous pollutants (NO_X, SO_2, CO), and solid particles emission. At gas-turbine plants is necessary to install continuous measurement of gaseous pollutants emission and flue gases opacity. CEM system at HEP's thermal power plants should include 22 boiler plants and 6 gas-turbines.

According to the By-Law the CEM system introduction in HEP's thermal power plants is analized on the bases of three applied approaches:

1. "one CEM system per stack"
2. "one CEM system per duct entering into the stack"
3. "one CEM system per each source".

Depending on applied approach, total number of necessary systems vary from 14 to 28. Approach "1" needs introduction of the smallest number of systems, but in some cases (more different furnaces with the common stack) it is not applicable. Approach "3" would make independent monitoring of all individual shares in total emission possible, but in the same time, results with the biggest number of required systems. Approach "2" is between extreme approaches "1" and "3", and it seems to be logical and justified sollution.

The data, that has been used for preliminary estimation of total capital costs, are based on the offers collected from five manufacturers. The range of evaluated total investment is from 1,9 to 4,4 million DEM. The lowest capital cost of CEM system introducing is by the approach "1" and by extractive measurement of gaseous pollutants, and the highest one is by the approach "3" and by in-situ measurement of all pollutants. It must be noted that we talk about preliminary evaluation realized in given conditions and by the mentioned assumptions.

It is logical to expect the application of the variant that would be somewhere between approaches "1" and "2", but the whole line of factors will influence on the final decision about choosing the right conception and optimal sollution.

In consideration of complexity of analized problems and relatively poor experience in Croatia, concerning the introduction of CEM systems, there is a need for intensively manufacturers joining in the future analyses. Some companies have already shown interest for cooperation, especially through thematic presentations where they would discuss about introducing the CEM system into the HEP's thermal power plants.