BULETINUL ŞTIINŢIFIC AL
UNIVERSITĂŢII "POLITEHNICA" DIN TIMIŞOARA

SERIA MECANICA
Tom 47(61),2002

Transaction on
MECHANICS

X-th CONFERENCE ON MECHANICAL VIBRATION
TIMISOARA 2002

A NEW GLOBAL ESTIMATION OF THE ATMOSPHERE POLLUTION DUE TO THE THERMOPOWER PLANTS

Malvina BAICA *, Mircea CÂRDU **

Abstract

In this paper we present an analytic methodology which, from the ecological point of view of Thermo Power Plants (TPPs), takes into consideration the noxious emissions into the atmosphere. Applying this new methodology could actually reduce restrictions imposed on the energy-producing TPPs, by admitting the possibility of compensating for the diverse noxious emissions effects.

Key words: Thermo Power Plants (TPP), environmental protection

1. Introduction

The impact of the thermopower plants (TPPs) on the surrounding environment, especially regarding noxious emissions by stack flue gas evacuation, represents one of the most pressing problems, as much in the construction of new TPPs as in attempts toward rehabilitation / modernization (R/M) of the old ones.
Evacuated flue gases from stacks of TPPs contain the following noxious emissions: carbon dioxide (CO_2), sulphur oxides (SO_x usually reduced to SO_2) and nitrogen oxides (NO_x); we consider the (CO) emissions to be negligible.

* DEPARTMENT OF MATHEMATICAL AND CONPUTER SCIENCES,
University of Wisconsin Whitewater, WI, USA
E-mail: baicam@post.uww.edu
** SOCET S.A.
Bucharest, Romania
E-mail: socet@dnt.ro

Presently, methodology dedicated to the analysis of noxious emissions of TPPs involves the comparison of noxious flue gases concentration with the maximum admissible limits imposed by norms currently in force.
In Romania these norms were established in the 462/1993 order issued by the Water, Forests and Environmental Protection Department (Ministry) [3].
The limit values for the noxious gas concentrations have as the unit measure [mg/m^3N]. Thus they represent the respective noxious gas content (expressed in mg) in a (normal) cubic meter of flue gases evacuated at the stack.
These limits are differentiated as a function of the type of fuel used (solid, liquid or gaseous), of the installation's thermal power, and of the respective installation category (new or old installation).
We note that, in conformity with the above-mentioned norms which for these new installations are already in accordance with the European standards, there is a requirement that these emissions conform to the corresponding limits of each individual noxious gas, without accepting *compensations* between the concentration values of different noxious gases, meaning that, if we obtain a concentration value of one of them which is lower than the admissible limit, then higher values than the admissible limits for another noxious gas are acceptable, provided that the noxious effect of all these put together does not exceed their cumulative effect when each individual one has a concentration limit.
Such an approach to noxious gas analysis (accepting a *compensation* among them), while not illogical would relax the pressure felt by energy producers in TPPs from the point of view of respecting the ecological standards.

2. Equivalent Carbon Dioxide

As result from the previous section, there is a need for a *key* to the equilizing of the harmful effects of some of the noxious contents in the flue gases, with those of others. To solve this problem we appealed to the CO_2, SO_2 and NO_x concentration values which have similar effects on humans and where the maximum admissible concentration values of these noxious gases in the atmospheric working zone is given by the working protection norms.
The corresponding values for SO_2 and NO_x were found to be equivalent to the CO_2 values (considering similar effects) and in the same way as in [1, 2], we defined *Equivalent Carbon Dioxide* (ECD) and we have the following relation for it:

$$(CO_2)_e = (CO_2)+700(SO_2)+1000(NO_x) \quad (1)$$

We can interpret relation (1) to mean that the noxious effect of SO_2 is 700 times more powerful etc. In this way we simplify the ecological analysis of TPPs. Instead of considering each noxious gas in particular we only appeal to the ECD $(CO_2)_e$.
If we refer to the maximum admissible concentration norms (standard) for the noxious gases, symbolized by the index "S", then we will have a corresponding ECD of these gases, which is given by the following relation (2), which is equivalent to the relation (1):

$$(CO_2)_{es} = (CO_2)+700(SO_2)_s+1000(NO_x)_s \quad (2)$$

Each individual fuel is characterized by a certain value of the $(CO_2)_{es}$, as we can see in table 1, which gives some characteristics of the liquid and solid fuels currently used in the Romanian TPPs. These characteristics are very interesting in the analysis which follows. Thus (S) represents the sulphur content of the fuel, Q_i is the lower caloric power of the fuel (in function of Q_i we calculate also the NO_x content in the flue gases [3]) and V_g is the volume of the flue gases corresponding to the unit mass of the fuel (denoted in kgf). With the values of V_g we calculate the (SO_2) and (NO_x) values which in the norms are given in mg per volume unit of flue gases (m^3N).

Table 1 – Characteristics of the liquid and solid fuels utilized in Romanian TPPs

Fuel	S	Q_i	V_g	CO_2	$(CO_2)_e$	$(SO_2)_s$	$(NO_x)_s$	$(CO_2)_{es}$
	%	$\frac{kJ}{kgf}$	$\frac{m^3N}{kgf}$	$\frac{kg}{kgf}$	$\frac{kg}{kgf}$	$\frac{mg}{m^3N}$	$\frac{mg}{m^3N}$	$\frac{kg}{kgc}$
	0.5	40835	12.391	3.208	21.638			40.098
	1.0	40720	12.360	3.190	28.590			40.000
	1.5	40605	12.330	3.172	35.540			39.920
	2.0	40490	12.300	3.153	42.490			39.827
Fuel oil	2.5	40376	12.268	3.135	49.430	3400	600	39.685
	3.0	40260	12.238	3.117	57.220			39.540
	3.5	40146	12.210	3.098	63.300			39.460
	4.0	40031	12.177	3.080	70.280			39.360
	4.5	39926	12.146	3.060	77.260			39.280
	5.0	39801	12.116	3.043	84.140			39.180
Lignite of Rovinari	0.7	6352	3.085	0.733	12.183	50%	800	8.100
Pit coal of Deva	1.775	15195	5.240	1.435	33.125	maximum	for PT**	18.060
Pit coal of Doicești-Șotânga	0.6	10586	4.246	1.111	14.271	sulphur emission rate*	> 150 MW	8.711

*) for boilers with remaining lifetime more than 15 years at 01.09.1998

**) PT = thermal power

Also, in Table 1 are given the carbon dioxide (CO_2) values which result from the burning of a kgf and which appear in both relations (1) and (2) as well as the maximum admissible values for SO_2 and NO_x by the norms. These refer only to the old energy-producing installations with thermal power greater than 150 MW.

Our analysis refers only to these, since there are no plans to construct more of this type of installations in Romania in the near future.

In the last column of Table 1 we give the values of $(CO_2)_{es}$ calculated with the help of relation (2).

To calculate the CO_2, SO_2 and V_g we used the relations describing fuel combustion in the boilers [5]

In the fuel oil case we made the calculations for various values of S content (between 0.5% and 5%) since this problem (maximum admissible S content) constitutes a widely disputed element in the actual economic conditions of Romania, where the price and the import location of the fuel oil are very important. For the calculations of Q_i value as a function of the fuel oil chemical composition we used the relations describing the combustion of the fuels as in [4].

It is well known that for the NO_x and SO_2 content reduction of the flue gases we use systems and installations [3] which can be grouped in the following four categories, characterized respectively by DENOX process efficiency (σ_n) and by DESULPH (σ_s):

- Primary DENOX (PDN), with $\sigma_n \leq 0.6$;
- Secondary DENOX (SDN) which is used only in a primary DENOX completion, in the case when both (PDN+SDN) are applied together yielding DENOX efficiency values $\sigma_n \leq 0.9$;
- Desulphurization by dried proceeding (pulverized limestone injection in the furnace of the boiler) considered as primary desulphurization (PDS) with $\sigma_s \leq 0.5$;
- Desulphurization by wet proceeding considered as secondary desulphurization (SDS), for (PDS)+(SDS) having $\sigma_s \leq 0.9$.

The introduction of these systems and installations in TPPs is very expensive.

In order to consider the effects of such systems and/or installations on the ECD values, in relation (1) and respectively (2), we introduce the measures of the values σ_n and/or σ_s. thus, the relation (1), for example, will be of the form:

$$(CO_2)_e = (CO_2) + 700(1-\sigma_s)(SO_2) + 1000(1-\sigma_n)(NO_x)_s \qquad (4)$$

In our case, for coal, the norm requirements are reproduced in Table 1, and $\sigma_s = 0.5$.
Accepting the validity of the compensation principle between SO_2 and NO_x mentioned before and considering the expenses, as well as the practical and technological aspects in connection with the dimensions and the placement possibilities of DENOX and DESULPH installations, especially in the existent TPPs, it appears that the following order of adopting them is optimal: PDN, PDS, SDS, SDN.

3. Conclusions

Presently the TPP_s operational analysis from the ecologic point of view can be effectuated by means of a methodology which considers noxious emission conformity with the imposed legal limits for the flue gases in the atmosphere. This methodology, which requires the agreement with the norms of each individually mentioned noxious gas, does not consider possibility that the noxious effect of one type of gas, in a greater quantity than the legal limit, could be compensated for by a more reduced effect of another gas whose quantity is lower than the legal limit, as a result of some appropriate technical measures.
In the methodology presented in this paper, starting from a comparison between the noxious gases effects, we developed a measure which synthesized the effects of all of them, and this measure is named *carbon dioxide equivalent* (ECD). In this way, by calculating a ECD value based on the legal limit value for each noxious gas, we can accept the above-mentioned compensation.
In the Table 1 we remark that, in case of fuel oil, $(CO_2)_e < (CO_2)_{es}$ for $S < 1.5\%$. in other words, even applying the new methodology (noxious *compensation*) of the ecological point of view, it is not admissible to utilize in TPPs fuel oil with a S content $S > 1.5\%$. We mention that having in view only the maximum admissible value for SO_2 (without to use the *compensation* principle) the maximum admissible S content in the fuel oil is $S = 1.0\%$.
For all solid fuel (lignite and pit coals) we have $((CO_2)_e > (CO_2)_{es}$, resulting the necessity to apply DENOX and DESULPH systems in the order: PDN, PDS, SDS, SDN, mentioned in the previous chapter.

References

[1] **CÂRDU M., BAICA M.,** *Regarding a global methodology to estimate the energy-ecologing efficiency of thermopower plants,* Energy Conversion and Managemet (ECM) 40 (1999), Nr.1, pp.71-87

[2] **CÂRDU M., BAICA M.,** *Regarding a new variant methodology to estimate globally the ecologic impact of thermopower plants,* ECM, 40 (1999), 1599-1565

[3] **IONEL I., UNGUREANU C.,** *Termoenergetica şi mediul,* Editura Tehnică, Bucureşti, 1996

[4] **LEMNEANU N., CRISTEA E., JIANU C.,** *Instalaţii de ardere cu combustibili lichizi,* Editura Tehnică, Bucureşti, 1982

[5] **UNGUREANU C.,** *Generatoare de abur pentru instalaţii energetice clasice şi nucleare,* Editura Didactică şi Pedagogică, Bucureşti, 1977