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Air Pollution Problems in Czechoslovakia

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Air pollution problems in Czechoslovakia

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The air pollution problem is one of the drawbacks associated with large industrial developments.

Because the solution to atmosphere pollution has been delayed, considerable damage and losses appear in regions of high concentration of industry, so much so that limitations may be placed on future industrial developments if no satisfactory solutions are found.

In Czechoslovakia the consumption of electric power is approximately doubling every ten years. Owing to the limited fuel possibilities, most of the new power stations will have to use inferior lignite fuels with a high sulphur and ash content, of a heating capacity ranging from 2.3 to 3.5 Mcal/kg, and of sulphur content from 1.5 to 9.3 g/Mcal. The disadvantages of this fuel, compared with black coal, are the following:

(1) A high sulphur content and thus also of sulphur oxides in flue gases emitted from the stack. For an 800 MW power station it amounts to approximately 7 kg of SO_2/s.

(2) It doubles the required capacity of the fuel and slag handling equipment, and the sizes of mills and boiler.

(3) Increased demands on the dust-separating efficiency of the dust collectors.

(4) A higher internal consumption of power necessary for coal grinding.

(5) A lower boiler efficiency.

(6) A higher rate of wear, especially of convectional surfaces of the boiler.

With regard to the coal transport costs, the new power stations are built and ought to be built in the North-Bohemian region in the neighbourhood of the lignite mines. There are both unfavourable climatic conditions and a high industrial concentration in this area. Great losses in the forest cover and adverse effects on the health of the inhabitants have been experienced there already.

Thus the construction of new power stations without desulphurizing equipment would be impossible in this region.

The solution of the air pollution problems in our country can be divided into three parts:

(1) Research and development of flue gas desulphurizing equipment.

(2) Continuous measurement of the background pollution and, if possible, the reduction of pollution sources.

(3) Investigation of dispersion conditions of flue gases from tall stacks.

The development of the flue gas desulphurizing equipment

This problem has been solved by the chemical section of the research institutes. From the results of the operation of the experimental flue gas desulphurizing equipment on a 5 MW unit, the desulphurizing equipment for a 110 MW unit is being designed, which is to be put into operation in 1971. If good results are obtained the power stations built in the future would be provided with this equipment (non-cyclic ammonia process). The installation of desulphurizing equipment will be considered for the power stations built up to that time.

The prediction of future air pollution is based on the known background and future planned industrial development in the region. The problem of flue gas desulphurization of large power plants has not been satisfactorily solved from the technical and especially the economic point of view. Therefore it is necessary to take into consideration the fact that in the near future it will not be possible to carry out the complete desulphurization of flue gases of all power plant units. In this case these power plants will be built in a suitable backgroundless region and/or with only a partial flue gas desulphurization.

Dry extraction of SO_2 from the flue gases is still in the experimental stage and no plants are as yet envisaged with this equipment.

On the basis of the results of the measurements in the environment of the power stations (Němec 1965, 1966) and according to the work of Gartrell (1966), the stage of flue gas desulphurization necessary for new power stations has been stipulated.

According to Sutton, the concentration with isotropic dispersion is given by the formula

$$c_{\text{is}} = 235\, Q_{\text{s}}/uh^2.$$

The maximum 30 min concentrations according to the results of the work (Němec 1965, 1966) can be determined from the relation

$$c_{30\,\text{min}} = ac_{\text{is}},$$

where a is the field maximum factor and its magnitude is taken (0.4) (Němec 1965, 1966; technical report 1968); Q_{s} is the quantity of sulphur dioxide emitted from the stack (g s^{-1}); u is the speed of the wind at the stack top (m s^{-1}); h is the maximum height of the plume centre over the terrain (m).

The maximum allowable quantity of SO_2 can be calculated from these formulas, if the value $c_{30\,\text{min}} = 0.5$, stipulated by the standard, is substituted for $c_{30\,\text{min}}$:

$$Q_{\text{s}} = 5.33\, 10^{-3}\, uh^2.$$

The maximum quantity of SO_2 will be reached according to the above expression, at the flow rate u_{c}, when $\mathrm{d}Q_{\text{s}}/\mathrm{d}u = 0$, and at the same time $\mathrm{d}^2Q_{\text{s}}/\mathrm{d}u^2 > 0$.

For the plume rise resulting from Gartrell's work (1966), the values u_{c} and $Q_{\text{s, max}}$ have been calculated in the terms of dependence on the height of the stack and on the power station rating.

The maximum emitted quantity of SO_2, which is allowable for the most unfavourable case of the wind flow rate for the given power station, is shown in figure 1.

The necessary degree of flue gas desulphurization has been calculated by the comparison with the actual quantity of SO_2 arising from the combustion of fuel in the power station. In figure 2 these relations are shown for the 3×500 MW power plant and for the stack height of 225 m with the wet SO_2 extraction process and at absorption temperatures of 35 and 70 °C (308 and 343 K). For favourable dispersion conditions heating of the desulphurized flue gases to a temperature of 125 °C (398 K) is assumed.

In the report (Astrov 1968), the economical evaluation of the desulphurizing equipment (ammonia non-cyclic process) has been carried out for new power stations. In spite of the fact that such an evaluation is dependent on uncertain factors (sale and prices of desulphurization waste, etc.) the increase of costs, owing to desulphurization, amounts to 7 % of the electric power production costs. According to the results it is evident that the dry SO_2 extraction process is more advantageous in some cases.

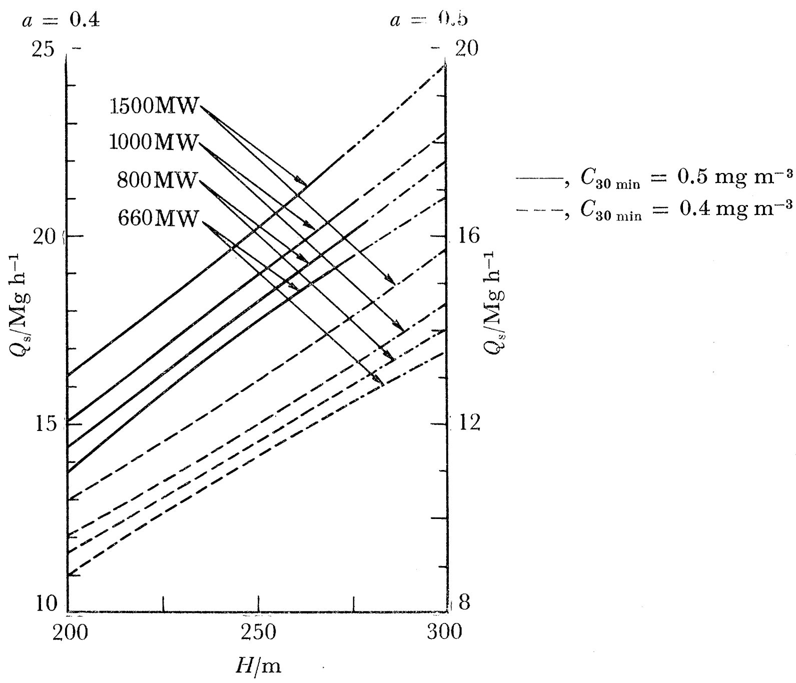

FIGURE 1. Q_s for two values of $C_{30\ \mathrm{min}}$, and various power station outputs plotted against stack height (H) for the range $a = 0.4$ to 0.5.

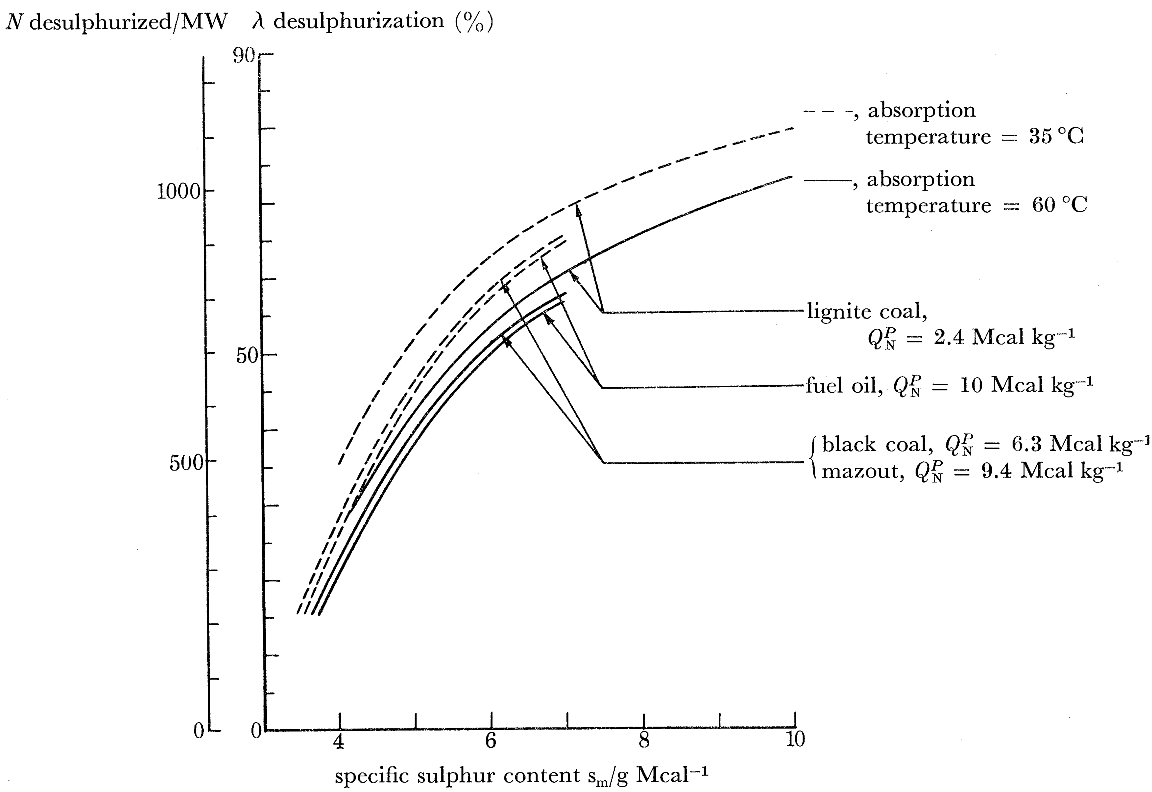

FIGURE 2. Required desulphurization percentage for the 3×500 MW power station, stack height of 225 m and $c_{30\ \mathrm{min}} = 0.5$ mg m^{-3}.

Continuous measurement of background pollution

As far as the second part of the problem is concerned, the sulphur dioxide content and the dust deposition in the region have already been measured for several years by summation methods similar to that of the lead peroxide candle and the standard deposit gauge. At present the measurements of SO_2 content are being carried out also by an aspiration colorimetric method (West–Gacke).

The measurement of dust content by means of concentrographs is under preparation. Here a moving filter collects the dust from the air drawn down a tube and the measurement is obtained by the absorption of light (Polydorová 1965). At the same time the burning of the surface lignite layers of open coal pits has been stopped. The heights of stacks of some old factories are being increased and tall stack power stations are built for electricity generation and for the heating of larger towns and plants.

Investigation of dispersion conditions

About twenty field experimental measuring studies of the spreading of plumes in the environment of power stations (rated from 100 to 660 MW, with the SO_2 emission rates from 1 to 5 kg/s) have been performed in the last ten years, mostly in flat terrain (Němec 1965, 1966). The SO_2 concentrations were measured at ground level, at thirty to fifty points of a 20 to 50° sector of a circle, downwind of the stack as far as 14 km distant. Furthermore, the speed and direction of the wind were measured, the stability of the atmosphere was ascertained and the plume rise photographed.

These measurements have given the following results:

(1) Data of actual concentrations in the environment of power stations, as functions of the emission and meteorological situation.

(2) Determination of some meteorological factors, for example of the ratio of the horizontal and the vertical components of the eddy diffusion from the distribution of SO_2 concentrations, in the longitudinal axis and in the cross section of the sector of the circle at ground level.

(3) From the measured parameters the values of the theoretical short-time maximum of the ground level concentration and the isotropic dispersion were calculated according to the Sutton formula

$$c_{is} = 235Q_s/uh^2,$$

where Q_s is the rate of SO_2 emitted from the stack ($g\,s^{-1}$); u is the wind speed at stack top ($m\,s^{-1}$); h is the maximum height of the plume centre over the terrain (m). These values have been compared with the maximum concentrations actually measured as 30 min means—$c_{30\,min}$. The ratio $a = c_{30\,min}/c_{is}$ includes both the influence of the anisotropy and of the duration of the sampling period, and may be called the 'field maximum factor'. The set of forty-four values of the ratio a is given in table 1; their values range from 0.07 to 0.45 (Němec 1968). It was found, by means of the Kolmogerov–Smirnov test, that the frequency distribution of these values is nearly normal. Then the probable values of their general mean have been calculated within the limits from 0.19 to 0.25 and their general standard deviation within the limits from 0.086 to 0.123.

On the basis of this work a group of experts headed by the State Committee for Technical Development have elaborated the 'Calculation methods of tall stack air pollution' (1968). These directions are taken as a basis for the calculation of the 30 min maximum concentration $c_{30\,min}$ for the critical wind speed, as we call it, at which the plume rise is equal to the height

Table 1. Field study, carried out at the power plants

N / MW	$10^{-3}Q$ / kg s^{-1}	h / m	u / m s^{-1}	$C_{30\,\text{min}}$ / mg m^{-3}	C_{is} / mg m^{-3}	$C_{30\,\text{min}}/C_{\text{is}}$
260	1.80	191	8.5	0.24	1.36	0.18
270	1.85	188	7.3	0.33	1.64	0.20
275	1.70	176	7.5	0.58	1.72	0.34
275	1.65	178	7.5	0.68	1.63	0.42
275	1.60	178	7.5	0.38	1.58	0.24
275	1.55	173	7.5	0.69	1.62	0.24
275	1.40	167	7.5	0.45	1.57	0.29
275	1.35	172	7.6	0.60	1.41	0.35
275	1.35	175	7.7	0.38	1.35	0.28
275	1.65	170	7.7	0.37	1.75	0.21
270	1.85	163	7.7	0.48	2.12	0.23
270	1.85	158	8.0	0.40	2.17	0.18
270	1.85	157	8.0	0.46	2.17	0.21
275	1.85	163	7.4	0.18	2.21	0.13
270	1.83	160	7.4	0.39	2.30	0.17
270	1.85	154	7.0	0.36	2.61	0.14
270	1.85	155	6.9	0.17	2.63	0.07
255	1.75	152	6.2	0.30	2.87	0.10
250	1.70	153	6.1	0.36	2.80	0.13
270	2.30	194	4.2	0.28	3.41	0.08
270	2.35	207	4.7	0.30	2.74	0.11
430	4.35	330	6.1	0.25	1.52	0.16
430	4.25	340	5.3	0.36	1.60	0.22
430	4.25	365	4.4	0.26	1.70	0.15
470	5.2	245	14.5	0.50	1.40	0.36
475	5.0	245	14.5	0.42	1.35	0.31
476	5.2	245	14.4	0.27	1.25	0.22
485	5.5	235	16.3	0.33	1.27	0.26
500	5.7	235	15.9	0.53	1.34	0.40
500	6.0	245	14.6	0.33	1.41	0.23
520	5.7	315	7.9	0.21	1.71	0.12
525	5.9	320	7.1	0.32	1.90	0.17
532	6.1	370	5.3	0.23	1.97	0.12
532	6.3	415	4.6	0.15	1.87	0.08
535	6.1	420	7.0	0.22	1.70	0.13
430	4.5	285	9.9	0.20	1.37	0.15
430	5.4	265	9.7	0.16	1.90	0.09
539	3.7	315	14.6	0.18	0.60	0.30
538	4.0	310	15.3	0.29	0.64	0.45
537	4.3	310	13.9	0.13	0.76	0.17
537	4.6	320	14.0	0.29	0.75	0.39
536	4.9	320	13.7	0.22	0.82	0.27
470	4.6	310	14.0	0.19	0.77	0.27
400	3.8	310	14.3	0.21	0.65	0.32

N, plant output; Q, emission rate of SO_2, h, plume height $(H+\Delta h)$; u, wind speed at stack top; $C_{30\,\text{min}}$, measured 30 min field maximum; C_{is}, short term maximum under isotropic dispersion, calculated from measured data.

of the stack ($h = 2H$). The field maximum factor is taken at the value $a = 0.4$. Then the maximum concentration

$$c_{30\,\text{min}} = c_{\text{is}}\,a = \frac{235\,Q_{\text{s}}}{u_{\text{c}}(2H)^2}\,0.4 = \frac{23.5\,Q_{\text{s}}}{u_{\text{c}}H^2}$$

from the plume rise formula, given further, the critical speed

$$u_{\text{c}} = AQ_{\text{h}}^{\frac{1}{4}}/H,$$

where Q_{h} is the thermal emission rate of the stack gases (MW), so that

$$c_{30\,\text{min}} = 23.5Q/AQ^{\frac{1}{4}}H.$$

(4) Data on plume rise and derivation of the relations for its calculation. Böhm has proved that the results of the plume rises (1965) measured by him, are in a good agreement with the formula

$$\Delta h = AQ_{\text{h}}^{\frac{1}{4}}/u$$

first proposed by Lucas, Moore & Spurr, where $A = 130$, for a power station with a 120 m stack and $A = 250$, for a power station with a 200 m stack.

Long period measurements have been started in the North-Bohemian region, to find the relations between the emissions, surface concentration and between the parameters influencing the spreading of plume in the hilly terrain of the frontier mountains. The stacks of two power plants are situated in the direction perpendicular to the ridge of these mountains (figure 3).

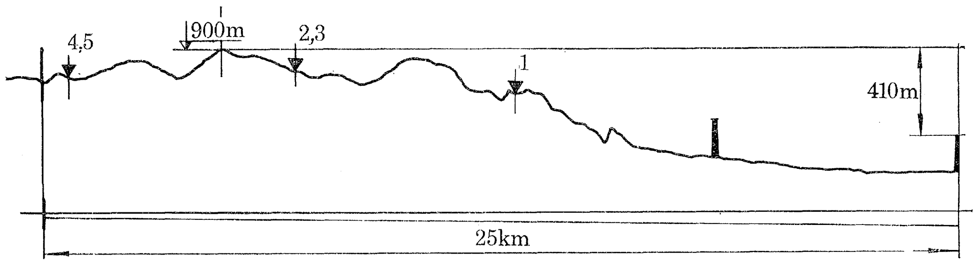

FIGURE 3. Profile of the terrain contaminated by flue gases from two power plants at the wind direction in the connecting line of the stacks. 1, 2, 3, 4 and 5 are points of continuous measurement of SO_2 content in the ground level atmosphere.

Therefore the sulphur dioxide recording instruments have been installed on the hillsides as well as on the top of the mountains on the line joining the stacks of the power plants mentioned; for the time being at five points with two at each point. At the same time, the total quantity of sulphur dioxide emitted is measured in both the power plants. The wind parameters and the meteorological conditions are measured in the nearest three meteorological observatories. The statistical relations will be searched for, after results from a long period have been obtained (Hašek 1967).

In a polluted region, it is very important to know the proportion of the total pollution caused, for example, by a power plant with a tall stack. For this reason paired measurements are being planned, in which a constant quantity of a tracer shall be dosed continuously into the flue gases in the stack. The quantity of sulphur dioxide leaving the stack will be measured as well as the concentrations of sulphur dioxide and of the tracer, downwind, in the ground layer in the environment. The sulphur dioxide pollution caused by the power plant will then be calculated from these data.

For this purpose Freon 12 (CF_2Cl_2) and Freon 11 ($CFCl_3$) have been chosen as the most suitable materials from the point of view of chemical stability, measurement of very low concentrations, technical and economic availability and from the safety point of view. They can be traced in extremely minute concentrations (1 part/10^{10}), by the analytic method of gas chromatography. If this method were used for a power station of 660 MW output, the costs would amount to about 2000 Kčs (Czechoslovak crowns)/h, that is about £40/h. These costs can however be reduced even further (Šťastný 1967).

The field experiments are very costly. Therefore the scaling conditions for a small scale model of plume spreading in a hilly terrain to a long distance from the stack have been examined by a theoretical analysis of the basic equations of the unstable diffusion in the atmosphere (Podlaha

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

1967). This work has shown that modelling in wind tunnels is possible using tunnel speeds of 1 to 10 m s^{-1}.

The correlation between geometric similarity and the flow similarity is lacking for the time being, however. We have been able to formulate the criterion from a small scale model of the source size.

The establishment of new power stations in our country is seriously endangered by air pollution problems and therefore great attention is paid to their solution by the Czechoslovak Government.

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