ASD# 082

CIP-10 is mentioned in the comparisons

COMPARATIVE MEASUREMENTS WITH VARIOUS INSTRUMENTS: PROBLEMS IN THE EVALUATION OF DUST EXPOSURES IN THE HARD COAL MINING INDUSTRY

H.-D. BAUER* • K. Robock†

*Silicosis Research Institute, Bochum, FRG
†K. Robock Mining Research Institute, Essen, FRG

Dust measurements with the tyndalloscope for the evaluation of dust exposure in the mining industry were performed from the middle of the fifties until 1973. Threshold values based on this measuring procedure. For the introduction of measurements, the tyndalloscope was at first the suitable device since it obtains data per minute about time-referred concentrations. Measuring values could therefore be allocated to a defined working process, thus indicating priorities of dust development and introducing measures of dust suppression. The disadvantages of the tyndalloscope were the dependence of scattering light intensity not only on concentration but also on particle size.

Realizing that the evaluation of dust conditions according to mass concentrations of fine dust results in a more suitable risk evaluation than other measuring parameters had, in connection with the establishment of mass-referred maximum workplace values for the whole mining industry, the consequence of converting the whole measuring and evaluating system. Thus the tyndalloscope was no longer suitable for the general occupational medical assessment of workplaces since the allocation of intensity values could not be realized in individual cases (Figure 1). Due to conversion to gravimetry, partly very different, evaluations of dust conditions in comparison with tyndalloscope assessments could be observed. Including tyndalloscope measuring data in epidemiological studies raised therefore many uncertainties about earlier critical dust conditions.

In the FRG, maximum workplace concentrations are derived from the Johannesburg Convention fine dust definition. The MPG II equipped with a horizontal elutriator (Figure 2) theoretically meets this defined fractionation. In the following time, it served as reference instrument in the German mining industry. When using devices with other separating functions comparative measurements with the MPG II are obligatory to determine whether conversion relations with a sufficient statistical significance are present. The TBF 50 (Figure 3), a double-cyclone instrument, used in routine measurements without follow-up filter behind the second cyclone, was tested in 180 comparative measurements. Concentration levels are compared in Figure 4. Because of the formerly supposed global connection between ash proportion and dust particle size, a correction of TBF 50 values with regard to ash proportion was tried. Based on these calculations, a corrective diagram was made (Figure 5) which was referred to for the indication of concentration-equivalent values for the MPG II. Obviously, alterations of mining and support techniques as well as of mine layout have increasingly blurred the connection between ash proportion and dust particle size. Thus, a correction via ash proportion is questionable at present. According to recent research findings, the conversion factor between these two instruments is independent of this parameter (Figure 6). The individual registered measuring positions represent mean values of 3 to 4 measurements at the same positions over a whole shift. Any position reflects various faces with different coal types and different mining techniques.

Relating the results obtained by the TBF 50 instrument with and without filter, a dependency of dust retained in the second cyclone on dust particle size is still present (Figure 7). However, distributions are also enormous when referring to dust particle size so that further influences are supposed to play a role. They might occur due to concentrations considering that cyclone efficiencies in addition to the particle size of dust to be collected also depend on concentrations. Furthermore, aggregates of suspended dust may be destroyed in cyclones. This factor has also an effect on dust masses separated in individual stages, thus being able to falsify the reference to primary conditions of airborne suspended dust. Dust may show various aggregation degrees which could not be correlated to defined workplace atmosphere parameters up to now.

The dependence of cyclone efficiencies on suspended dust uptake is also revealed in a comparison with the personal dust sampler Simpeds 70 MK II. In case of high concentrations, the throughput decreased which had the consequence that less dust was separated on the follow-up fine dust filter (Figure 8). In addition, varying flow velocities had a substantial effect on the collecting capacity of the intake. When performing alternating measurements with both instrument types, these parameters should be considered for concentration determinations.

Different conversion factors had to be taken into account, too, in a comparative test using the French device CIP 10 (Figure 9). Applied at the same position and at the same time hitherto obtained test results of instruments show a de-

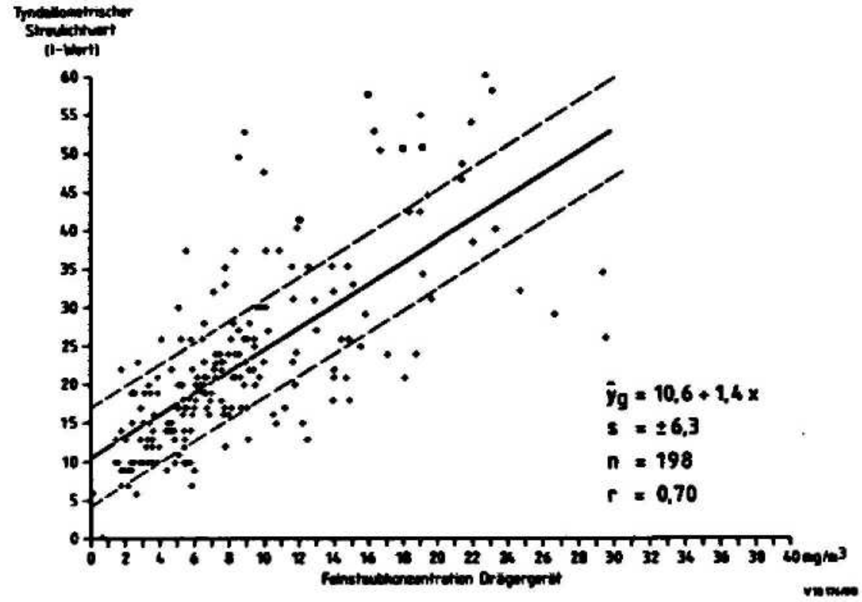


Figure 1. Comparison between tyndalloscopic and gravimetric measuring values.

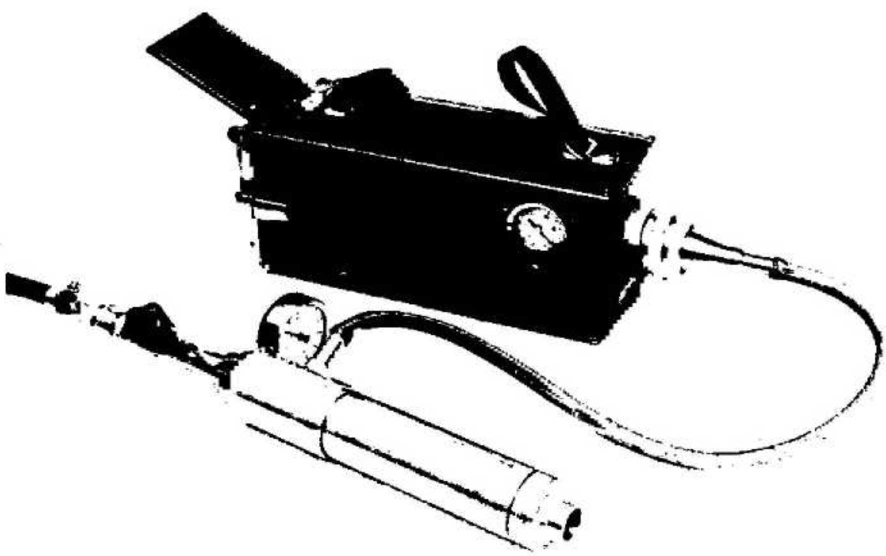


Figure 2. MPG II.

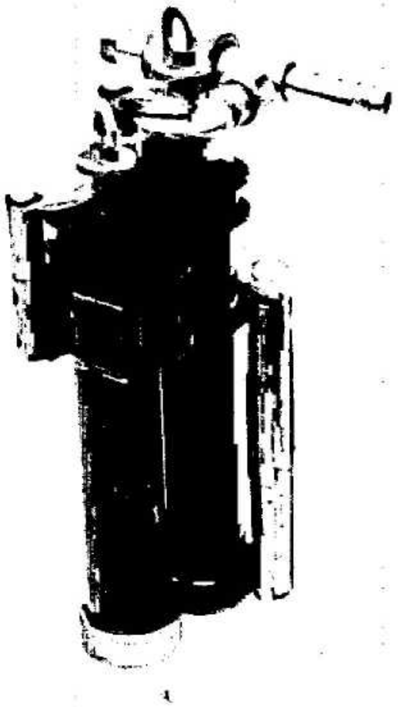


Figure 3. TBF 50

pendency of the conversion factor level on mined coal type as well as on mining method (Figure 10).

Outgoing from gas-flame coal, a low rank coal, and ending with high rank coal, the conversion factor increases, especially for plough mining. This tendency is less distinct when mining is performed with shearer-loaders. For this type of mining, uncorrected results of almost equal concentrations for MPG II and CIP 10 instruments can be based in general. The different reaction of both types during dust measurements in various mines applying different mining methods and the mining of coal with varying ranks is the result of different coarse dust pre-extraction in connection with varying particle size distributions of suspended dust. In one case for example, a change of mining methods from stripping to cutting resulted in the reduction of average particle size diameters by about 26 per cent. Likewise decreased the conversion factor from 1,4 to 1,1.

The outcome of these comparative measurements indicates the difficulty to use instruments with a deviating fractionation when referring threshold limits to a specific fine dust definition. Usually, general conversion factors cannot be applied; allocation has to be face-specific.

Due to the conversion to gravimetric methods, it is nearly impossible to recognize individual emitters and to proportionate them according to mining methods. Therefore, a new handy instrument, measuring on tyndallometric basis, was

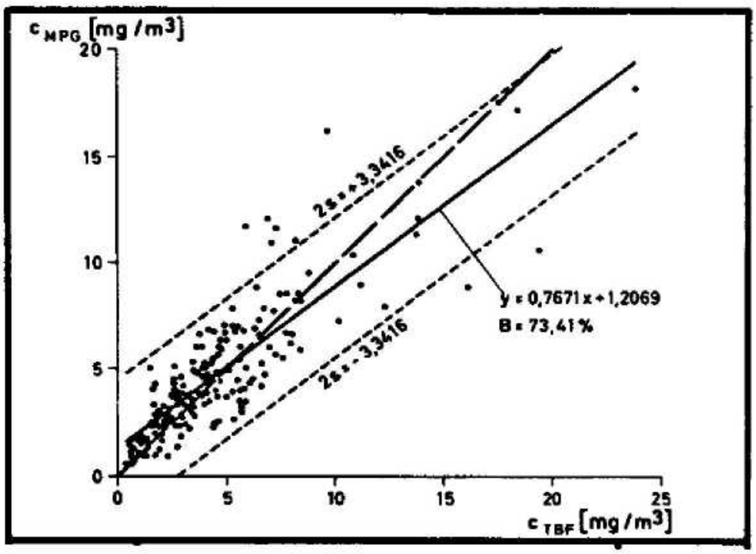


Figure 4. Concentration comparison between C_{TBF} and C_{MPG}.

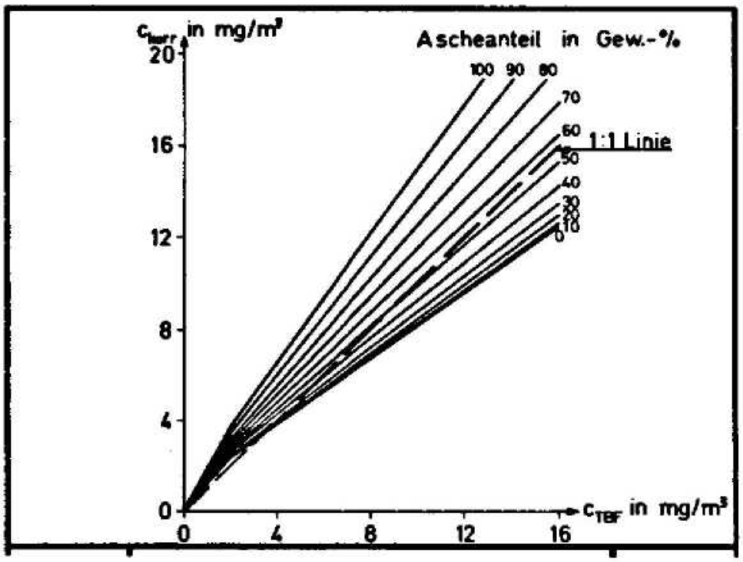


Figure 5. Conversion C_{TBF} into C_{corr}.

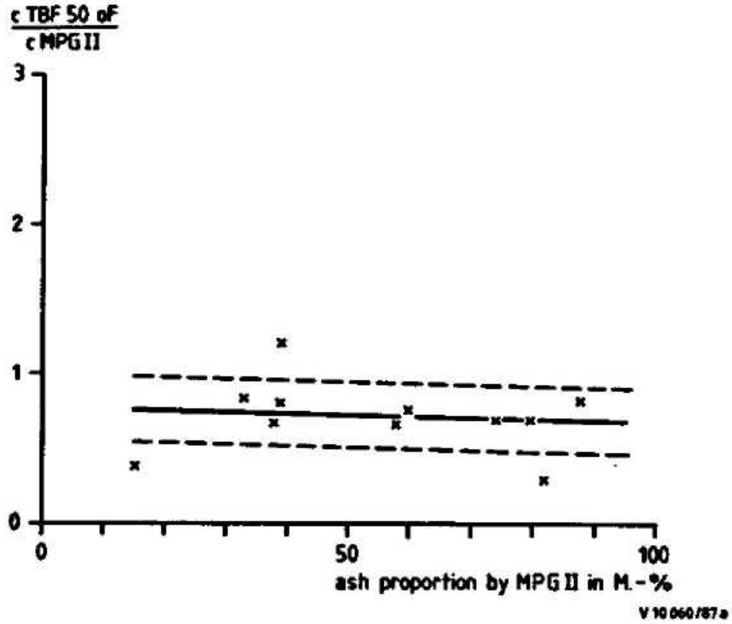


Figure 6. Ash proportion obtained by MPG II in mass %.

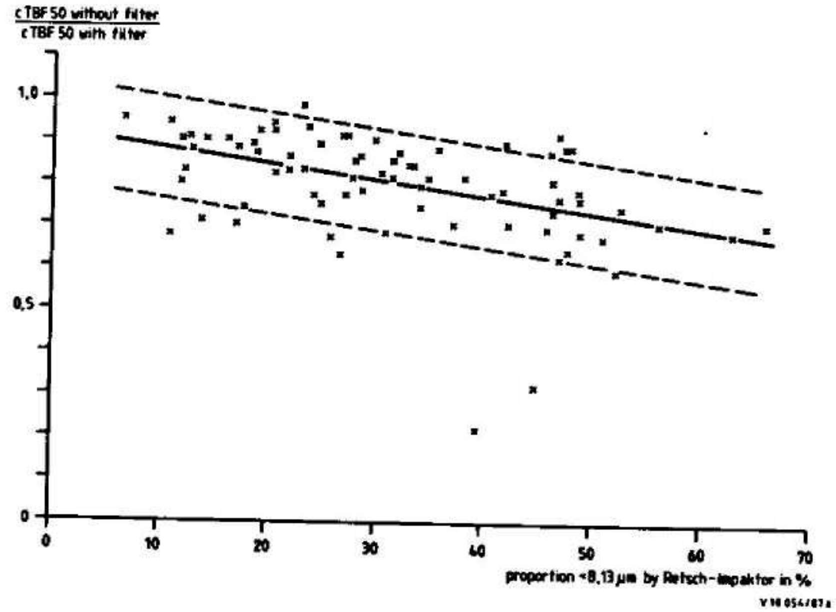


Figure 7. Conversion factors for TBF 50 with and without filter.

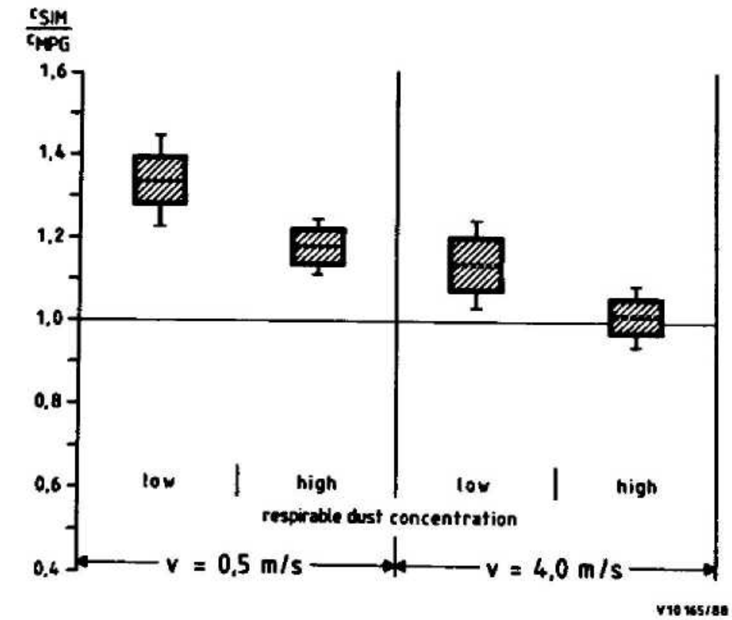


Figure 8. Conversion factors for Simpeds and MPG II.

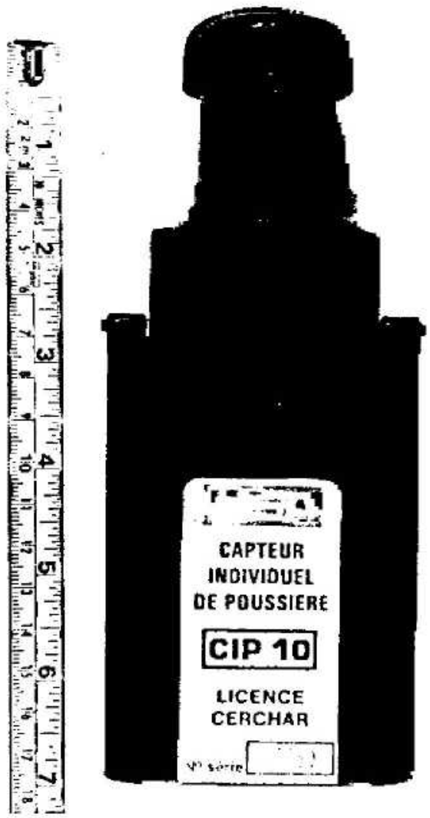


Figure 9. CIP 10.

developed: the TM digital µP which indicates single and average values for random measuring periods (Figure 11). Measuring sensibility due to particle size was diminished in this equipment. The advantages were mainly attained by measuring scattered light at an angle of 70° compared to 30° for the former tyndalloscope, and using monochromatic primary light of a wave length of 0,94 µm instead of visible light. Although the primary objective for using the TM digital µP was dust measurement for technical purposes it was also designed as supplementary or auxiliary device for occupational medical surveillance under specific operational conditions. At first, comparative measurements with the MPG II did not yield encouraging perspectives (Figure 12). The wide distribution of comparative values seemed to exclude an acceptable allocation of scattering light values to gravimetric concentrations. Classifying values according to specific characteristics of mining did not result in a substantial improvement, either. However, face-referred evaluations and limitation to areas of low exposures obtained good correlations between MPG II and tyndallometer (Figure 13). It is true that conversion factors vary widely from face to face; a linear relationship to comparative values is obtained, however, if a specific face is referred to.

At first, this assessment had the only objective to find out which tyndallometric measuring values have to be determined for the "worst case" in an area of low dust make and thus a low health risk in order to abstain from time-consuming gravimetric measurements. The linear correlations shown in figure 13, however. To prove this, comparative measurements during about 100 subsequent shifts were performed

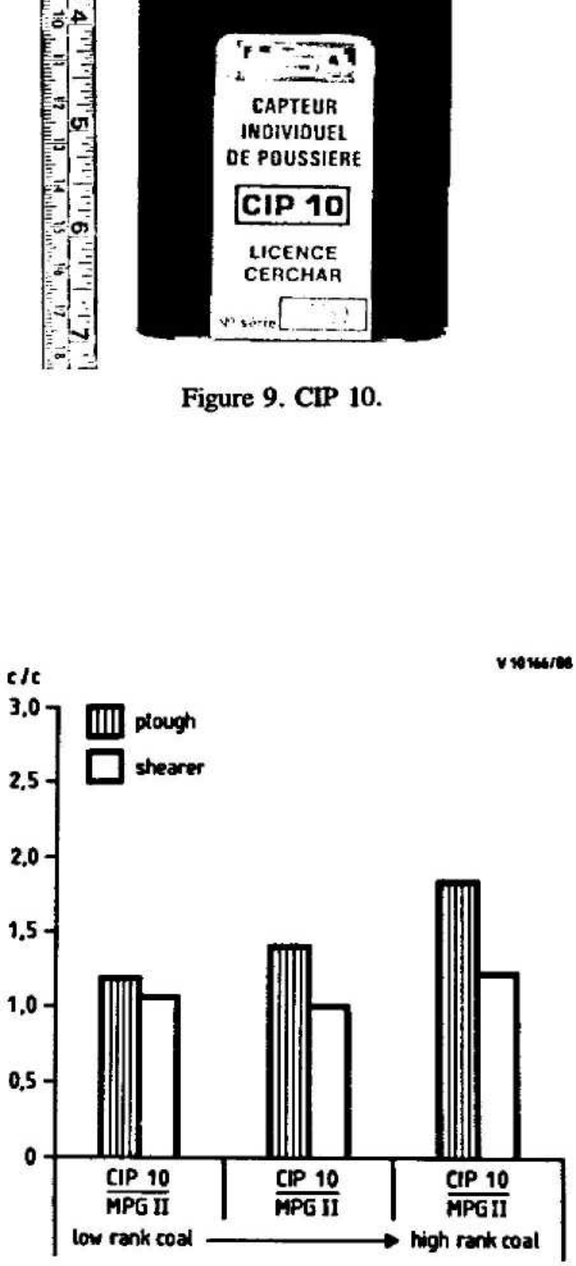


Figure 10. Conversion factors CIP : MPG II.

Figure 11. TM dig. µP.

in various mines with the TM digital μP, the MPG II, the TBF 50 and with a fine dust measuring device developed for permanent measurements with remote transmission of values on the basis of the tyndallometer digital μP. These devices were placed in a frame to maintain the same arrangement of instruments even when positions in mines changed (Figure 14).

To avoid dust deposits in the measuring chamber of the tyndallometric dust measuring device, clean air flows through a small fan at the inside of the measuring chamber. Speed

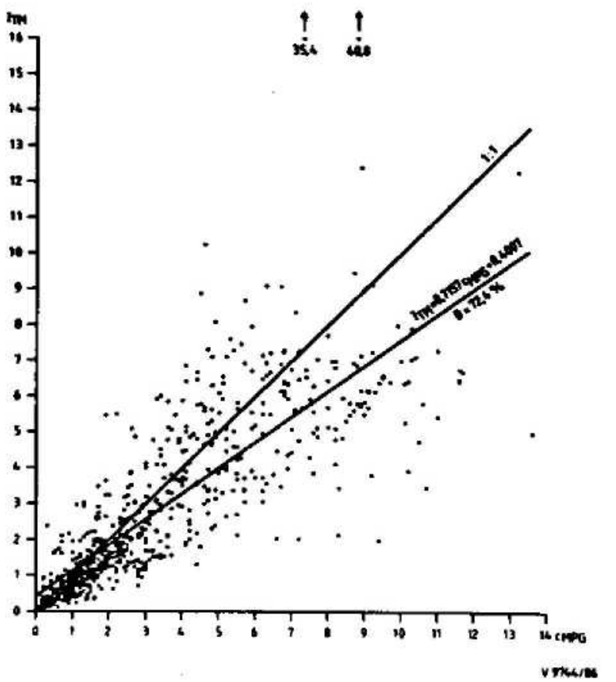


Figure 12. Relation between gravimetric and tyndallometric intensity values of respirable dust concentrations.

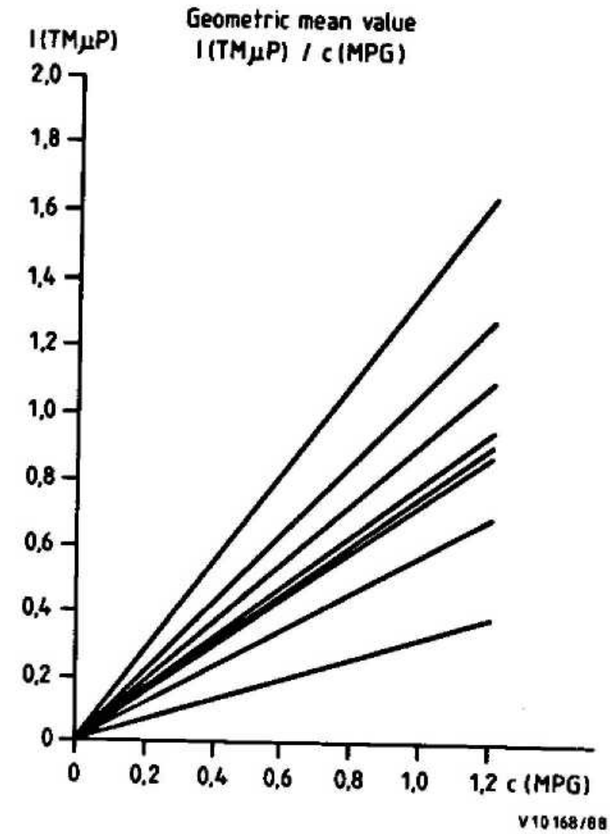


Figure 13. Conversion relation for different faces (low concentrations).

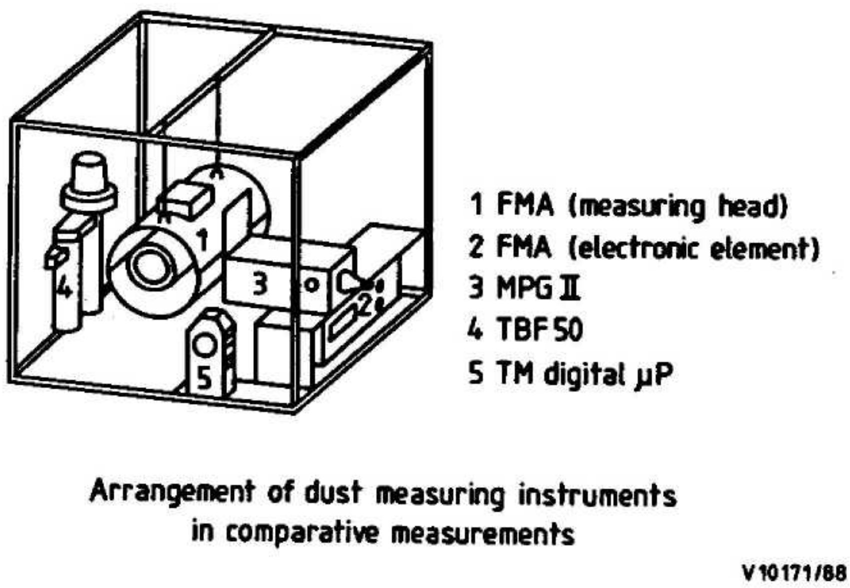


Figure 14. Arrangement of dust measuring instruments in comparative measurements.

can be adapted to environmental velocity. In order to illustrate the comparison of results achieved by the tyndallometric fine dust measuring instruments with those of other instruments a field test typical for instrument reaction is described. The comparison with the MPG II showed a linear correlation over the whole sphere of concentrations (Figure 15). This also includes the other field tests which show in some cases a varying increase of the balancing straight line. However, the positions of balancing straight lines are typical for each face. Their rise remains nearly unchanged during varying operational processes in the same face. Thus, a face-specific allocation to the MPG II is feasible but also necessary. In this case, the conversion factor is not only valid for short-term but also for long term periods.

Regarding the TBF 50, correlations are less distinct (Figure 16). The distribution is higher. In another case, an allocation was even impossible (Figure 17). Since measuring values of the tyndallometer can be face-specifically allocated to gravimetric measuring values of the MPG II as the basic instrument, the following consequences can be drawn:

1. It is suitable to give a review on dust conditions between two gravimetric measurements.
2. It can help to decide for which shifts of operational procedures gravimetric measurements are required and for which shifts separate measurements should be carried out.
3. It is apt to indicate whether normal dust conditions were prevailing in the time of gravimetric measurements in order to exclude positive or negative extreme situations which may influence long-term classifications of the face.
4. In particular cases, the interval between two gravimetric measurements could be extended under the condition that the frequency of tyndallometric measurements increases in the meantime or a permanent tyndallometric surveillance is provided.
5. Basically, tyndallometric measuring instruments offer the possibility to allocate short-term concentration changes to specific operational procedures, to introduce dust suppression measures and to check the efficiency of them.

However, the tyndallometric measurement will not be able to replace the gravimetric measurement. As far as test methods for the direct determination of specific fibrogeneity of a dust collective are not at disposal substance quantities obtained by gravimetric samplers will have to be classified more extensively than hitherto to acquire a better knowledge on changing proportions of individual components, their particle size distributions and information about their potential interactions in dust mixtures with regard to fibrogenic tissue reactions. Primarily, single particle analyses on homogeneous and heterogeneous compositions including element analyses by electron microscopy and Lamma spectrometry are required.

As in many other countries, the evaluation of quartz-including fine dust mixtures in the FRG is carried out according to total fine dust concentration considering the quartz proportion of this dust mixture. Quartz as individual mineral serves as reference value (Figure 18, middle-line). Thus, the approved fine dust concentration in case of quartz quantities <100% is an operand only. In the FRG, however, this method is not consequently applied in cases of low quartz

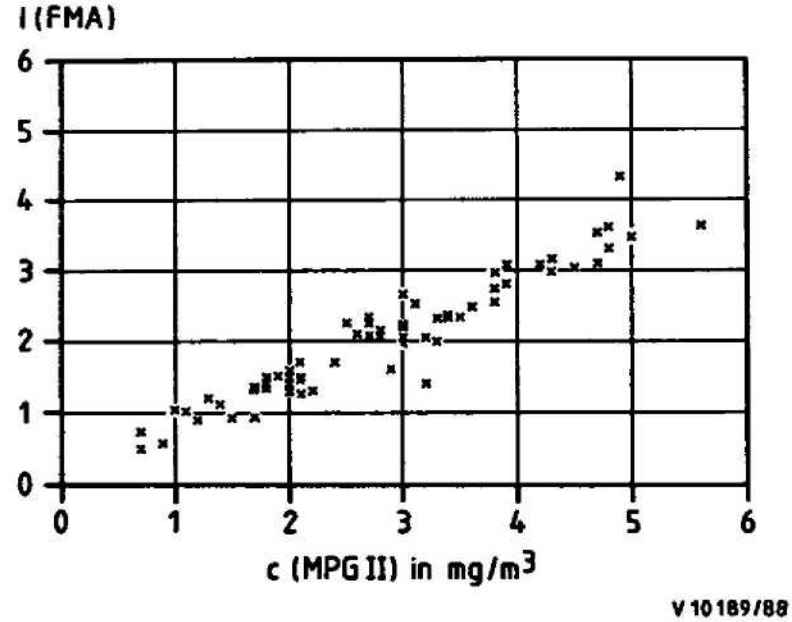


Figure 15. Comparison tyndallometer (FMA) and MPG II.

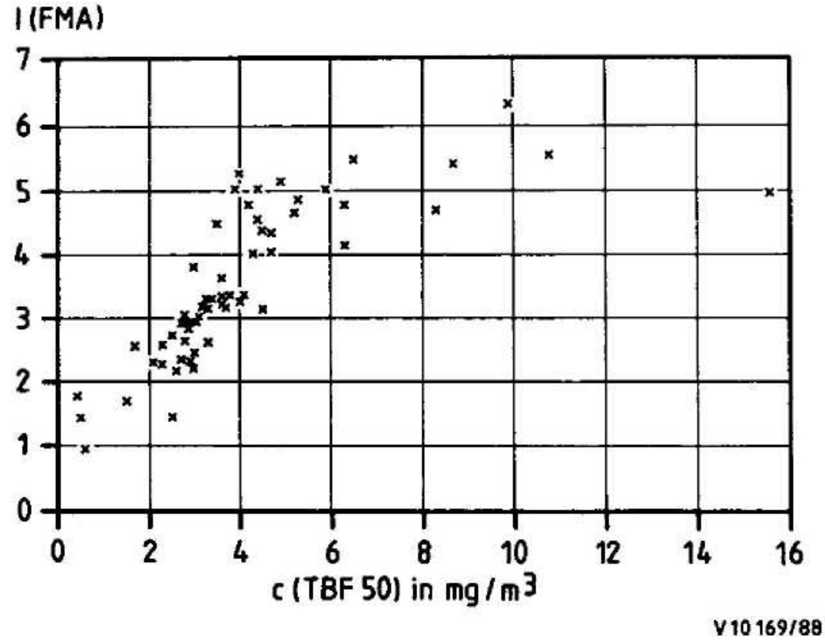


Figure 16. Comparison tyndallometer (FMA) and TBF 50.

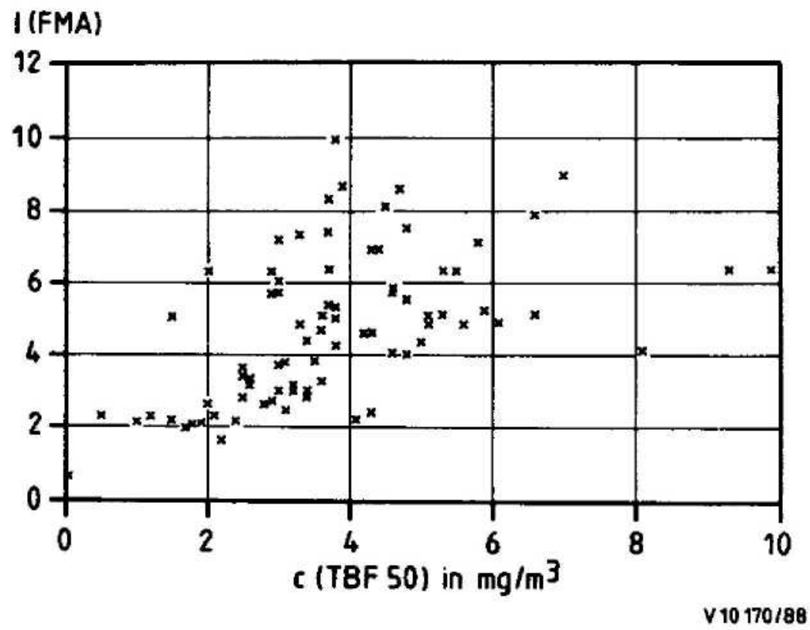


Figure 17. Comparison tyndallometer (FMA) and TBF 50.

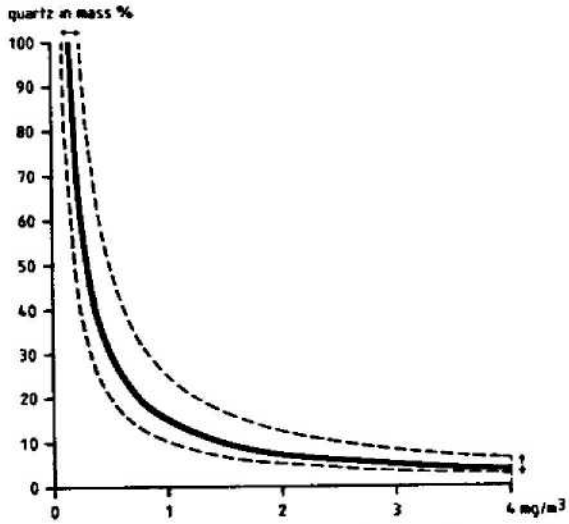


Figure 18. Scheme of bands for quartz concentrations in case of modified quartz evaluation.

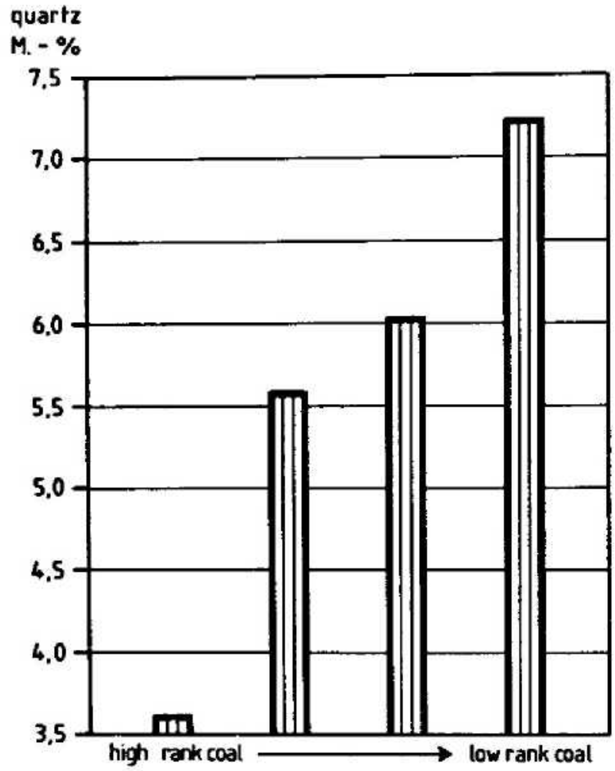


Figure 19. Quartz contents in respirable dust (measurement results obtained between 1980 and 1988).

proportions. In the presence of low quartz proportions, a defined fine dust threshold value was established which is not to be exceeded during a long-term assessment period. In case of small proportions, quartz is believed not to be the decisive biological parameter. At least in the hard coal mining industry it is doubted that quartz has the same fibrogenic power under any petrographic condition. Due to different developments, quartz as single component might show varying activities, or, referring to its harmfulness, it could be modified on account of interaction with other mineral components during or after deposit formation. For example, in spite of high quartz dust concentrations in a mine of a sedimentary hydroxide iron ore over a long-term exposure period did not provoke lung damages in exposed miners. At that time, this outcome was attributed to insoluble quartz surface masking.

In other hard coal mines, too, the risk to disease obviously cannot be directly and generally related to quartz fine dust concentrations. For example: the quartz proportion of dust originating from high rank coal is essentially lower than that of younger strata (Figure 19). The number of diseases is contrasting, however. These hints and findings raise two questions

1. Can occupational medical evaluation be based on a standardized quartz definition?

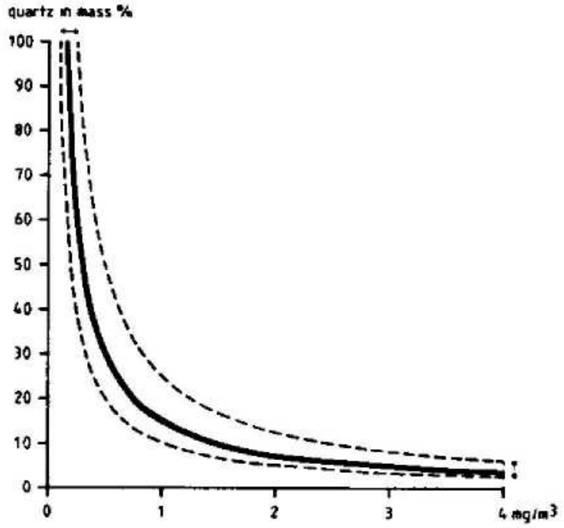
   When referring to pure quartz wouldn't it be preferrable to make modifications considering the different fibrogeneity and to fix specific limit values?

2. Is it justified to restrict approved total fine dust concentration mathematically only by taking into account the respective quartz proportion without considering the components in the dust mixture interacting with quartz?

Several countries might have based their limit values on reference values for quartz of different origin which have different effects, therefore. This could explain the partly widely varying approved mass concentrations. A well-known fact is that free crystalline silica has not only structural differences but also varying biological effects. The results of animal experiments after using quartz of different genesis but also with cristobalite, tridymite, coesite, stishovite as well as amorphous silica confirm these findings. This means that the conditions of quartz formation and of the growth of quartz crystals in the plutonic development from early release out of liquid magma up to the telethermal phase in the hydrothermal sphere can vary widely. Therefore, deviant effective potentials of the mineral which is generally regarded as quartz should be taken into account. The SiO_4 tetrahedron arrangement determining SiO_2 modifications does not seem to be decisive, but rather the undisturbed or disturbed formation of individual tetrahedrons, for example substitution of Si ions by aluminium or phosphor.

Under the condition that a specific limit concentration of for example 4 mg/m³ for respirable dust including quartz must not be exceeded the curve progression of the approved fine dust concentration considering the proportion of the modified quartz component would change (Figure 20). However, the potentially inhibitory effect of substances in the dust mixtures would not be taken into account when applying this purely mathematical procedure. A more reliable assessment might be possible if chemical, physical and mineralogical characteristics could be determined for the specific nocuousness of a total respirable dust collective. This assessment cannot be realized yet for the hard-coal mining industry. Subject of present discussions is a model to better adapt the occupational medical assessment of dust uptake in workplace atmospheres in case of exposure to dust originating from various stratigraphic horizons by means of correction factors. In case of an uncorrected reference to the quartz proportion, this mineral component in the dust of seams with low rank coal was the decisive parameter of the approved total fine dust concentration since the limit of 5 mass per cent was essentially exceeded in general. However, disease frequency in the presence of seams with high rank coal and substantially lower quartz components was much higher.

These different findings are intended to be harmonized by correction factors for exposure evaluation. This means that the quartz proportion in mass percent of seam strata with low rank coal has to be converted into an "effective quartz proportion" referring to the conditions in layers with a higher rank coal. Irrespective of this parameter, the fine dust concentration of 4 mg/m³ represents the maximum limit con-



Scheme of bands for quartz concentrations in case of modified quartz evaluation

Figure 20. Scheme of bands for quartz concentrations in case of modified quartz evaluation.

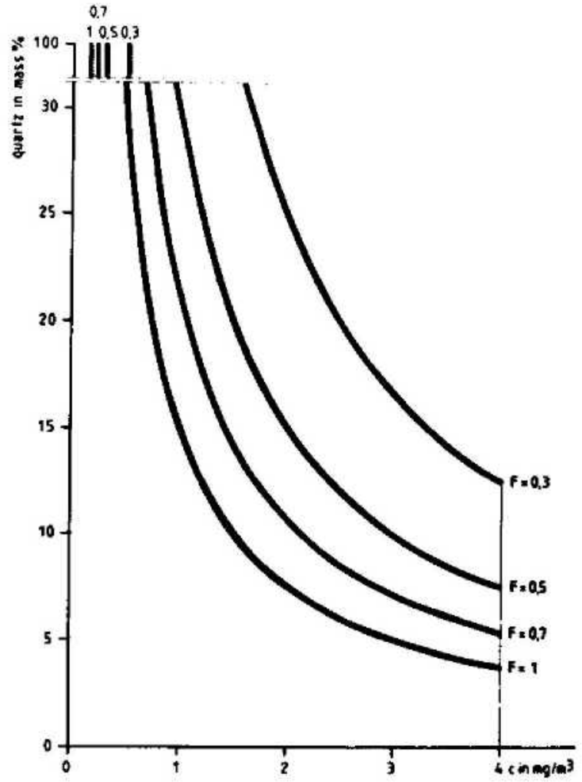


Figure 21. Approved respirable dust concentration in dependence on quartz proportion and the application of correction factors.

centration in an assessed period (Figure 21). In the practice, the consequences would be as follows: Applying factor 1, valid for seam strata with high rank coal, quartz evaluation would continue to begin for a quartz proportion of 5 mass percent in the German hard-coal mining industry. The further progression of approved respirable dust concentrations will ensue from the orientation to the pure respirable quartz dust concentration of 0.2 mg/m³. Using factor 0.5, quartz evaluation would start for a quartz proportion of 10 mass percent only, i.e., that the calculated respirable quartz fine dust concentration of 0.4 mg/m³ analytically determined via the quartz proportion in mass per cent would be converted into an effective concentration of 0.2 mg/m³. It is certainly not yet justified to provide as many categories for seam strata as shown in figure 21. A relatively rough differentiation into 2 or 3 groups of factors would be preferrable. In our opinion, the observed risk variations could be better taken into account by such a procedure, even when evaluating dust uptake in various stratigraphic horizons. Such a convention demands that the adaptation to an evaluation is restricted to modified factors of the quartz component until general systems to evaluate the specific nocuousness of the whole dust collective will be developed.