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Exposure to Non-Asbestos Refractory Materials: Corrections of Fiber Counts for Comparable Risk Assessment

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Many scientists believe that the dimensions of fibers are the main factor in their pathogenicity. According to this theory, which has been supported to a large degree by the work of Stanton et al (1981) it does not matter whether a particle is a feldspar asbestos or whether its form is due to growth, attrition or cleavage. As to the actual dimensions of fibers mostly connected with pathogenic effects, Stanton et al (loc cit) reports that fibers with aspect ratios >32:1 are the most involved; Cossette (1984) has summarized the criteria most commonly accepted regarding the relationships between fiber dimensions and their respirability: 1. The diameter of a fiber determines its respirability; 2. The length of a fiber determines its potential for being retained in the air passages; 3. The greater the aspect ratio (length/diameter) the greater its chances are of being inhaled and retained in the lungs (assuming the diameter is small enough to make it respirable).

Non-asbestos refractory (ceramic) blankets (NARB) release non-permanent fibers during operations of furnace insulation in the aluminum industry, which have been described in detail in the previous part of this report. During the last decade, NARB has replaced in these applications similar blankets and mortars which contained asbestiform particles, and there is agreement that this replacement has resulted in an appreciable reduction of the risk of inhaling pathogenic particles by the workers involved in the operations. The purpose of this contribution is to present exposure data of workers involved in furnace shop operations, and introduce a system to correct the fiber counts on the basis of reported inhalability and pathogenicity models (Pott 1978, Cossette 1978). The correction allows expressing the exposure risk on a comparable basis both between different work routines as well as between different uses within the aluminum plant. The expression of exposures at the work place on such a basis satisfies prevailing criteria on the need to find comparable evaluations of risk for the sake of an adequate planning of industrial operations (Whipple 1989).

MATERIALS AND METHODS

The following definitions are here adopted:

-Fiber (F): any particle with parallel sides, a diameter < 3 um, length >5 um and an aspect ratio >3:1

-Reference respirable fiber (RRF) number: The number of F fibers corrected through multiplication by a function of individual aspect ratios fitted to the average values of aspect ratios from post-mortem human lung tissues as reported by the Advisory Committee on Asbestos Cancer (ACAC) in 1978 (Cossette, loc cit, Table II).

-Pott´s pathogenic fiber (PPF) number: The number of F fibers multiplied by a function of fiber length and diameter which fits Pott´s pathogenicity model (Pott loc cit). This model was developed on the basis of results with cell cultures and animal experiments, and consists of two functions which relate the diameter and the length of fibers, respectively, with their tumorgenic potential. This is expressed as a fraction of the potential corresponding to very long (length greater than 20 um) and very thin (diameter about 0.1 um) fibers. Based on these functions, a factor ´f´ relating aspect ratio and tumorgenic potential was calculated. Table 1 reproduces the data used to derive ´f´ values, RRF and PPF counts.

Two types of working routines occurring at the anode baking shop will be discussed in this presentation. These correspond to maintenance operations performed at two different furnaces. In routine A, new NARB rolls are cut in narrow bands which are used to fill expansion joints at the walls and corners of the furnace chamber pits. This routine is performed continuously during the working shift, the worker remaining at the interior of the 1.5 x 5.00 x 8.00 m depth pit during most of the shift length. During this routine, the worker is potentially exposed to fibers released from new NARB and also from those released during the removal of old joint fillings from the previous furnace baking cycle. In routine B, the same task is performed as in A, but in this case 2nd. use blanket strips are used instead of new material, and the exposure is to fibers released from this as well as from 3rd. use joint filling.

Table 1. Basic data and fitting functions used to correct F non asbestos fiber counts for respirability and pathogenicity.

Aspect ratio (AR)	f Pott´s Model	f ACAC average data
4	0.010	0.025
6	0.050	0.044
10	0.105	0.248
15	0.160	0.348
20	0.280	0.432
30	0.460	0.680
40	0.650	0.728
60	0.750	0.890
100	1.000	0.950
200	1.000	0.970
400	1.000	1.000
700	1.000	1.000
Fitting equation: $f = a0 \ln AR + a1 (\ln AR)^2 + a2 (\ln AR)^3$		
a0:	-0.266	-0.184
a1:	0.182	0.167
a2:	-0.017	-0.016
r sq.:	0.990	0.995

Sampling and measurement of the number of air suspended fibrous particulate was performed by instantaneous conimetric probits (80) during the work shift in both cases. In this report, only the data corresponding to the first half shift (4 h) are presented. Data from the second half shift confirm all results here shown, since there was no major change in the work maintenance routine. Further details of the sampling procedure are given in the first part of this contribution. Based on the aspect ratio of all fibers in each probit ´f´ (POTT´s, ACAC´s) average probit values were computed, using the fitting equations in Table 1.

RESULTS AND DISCUSSION

Figure 1 shows the numbers of air suspended fibers (Total, PPF, RRF) collected during a work routine of type A. The major exposures were detected during the shift always in coincidence with a particular task which consists in the application of the NARB band inside the cleared expansion joint space. While performing this operation, the worker can be either standing on a ladder at medium height within the chamber pit (Fig 1, samples 11-15) or standing on the pit floor (Fig 1, samples 23-30, 39-40). At the pit floor, the air suspended particulate may contain

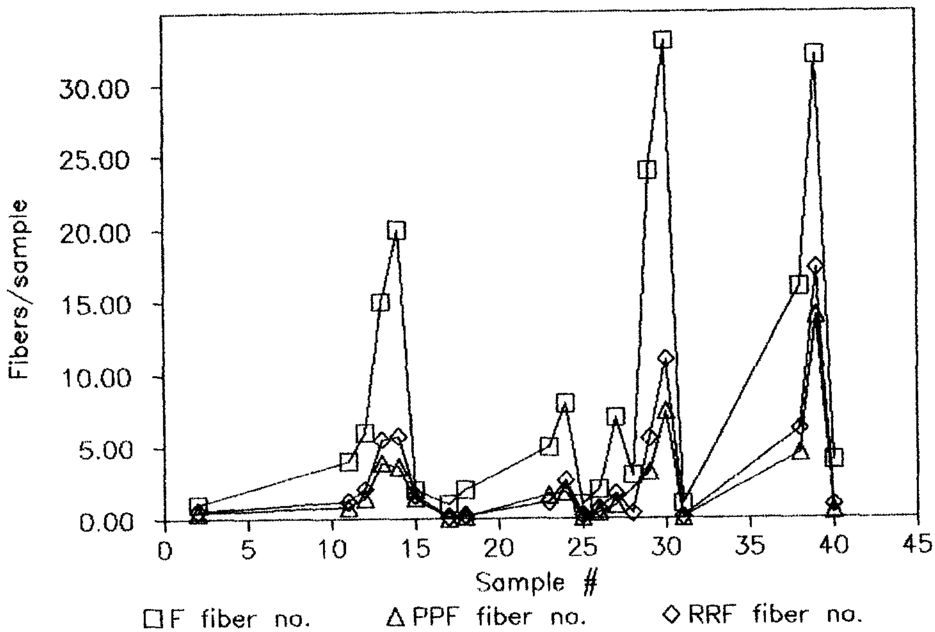

Figure 1. Fiber counts during a working routine of type A

material from 3rd. use torn-off joint fillings, which falls from the corners during the immediate previous removal. The operation performed in all cases consists in pushing the blanket band inside the joint space, which is achieved working on the band with the edge of a mason hammer.

Figure 2 shows the corresponding fiber counts when a worker performs a type B routine. The exposure peaks correspond to the moments when the worker inserts the blanket band inside the expansion joint space (Samples 26-29, 31-33) at top or middle height inside the chamber pit, standing on a ladder, or when the same was performed at the pit floor expansion joint (Samples 35-40).

It is observed that both PPF and RRF are similar and consistently lower than the total fiber counts, i.e., most of the fibers released from NARB are of aspect ratios which can be expected to be characterized by middle to low pathogenicity-respirability in the sense of POTT´s and ACAC´s models. The average correction:

$$f_{aver} = f_{POTT's,\ ACAC's} / n \qquad (1)$$

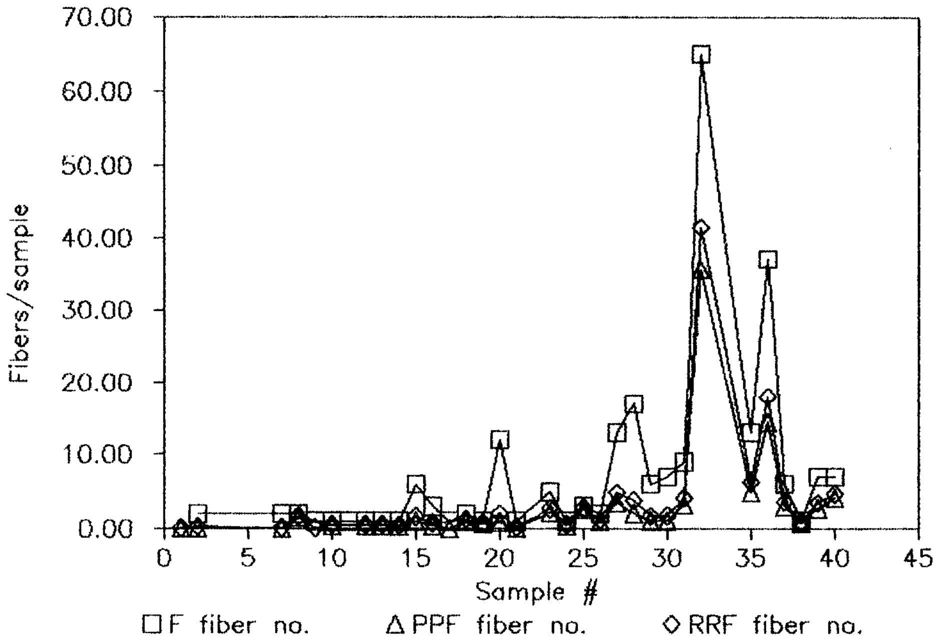

Figure 2. Fiber counts during a working routine of type B

where n is the number of probits obtained during the work shift time relates the average sample aspect ratios with those of maximum pathogenic-respirable fibers in the sense of POTT´s or ACAC´s models. The ratio varies from sample to sample depending on the contribution to air suspended fibers from NARB being worked, which has been previously submitted to various degrees of attrition or crystalization. The average f (POTT´s data) is 0.19 for the samples in Fig. 1, and 0.33 for those in Fig. 2, the difference between them being significant (t test, $p<0.05$). Similar values are obtained when inspecting the average f for ACAC´s data. The average f values are interpreted as a quantification of the reduction in exposure risk when performing the same maintenance operation with new (routine A) as compared to the same using 2nd. use NARB (routine B).

The analysis here shown allows correcting work procedures for the sake of attaining minimum potential exposure of the worker to fibers, and allows quantifying the relative risk when operating with NARB after exposure of the material to attrition and-or recrystalization.

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