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WORKING DOCUMENT

A REFERENCE SCHEME FOR QUALITY ASSURANCE OF FIBRE COUNTS BY PHASE CONTRAST OPTICAL MICROSCOPY

(Prepared for the WHO/IFSG working group of experts for harmonization of methods and quality assurance in the evaluation of exposure to airborne fibres in work environment)

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FOREWORD

According to a memorandum of understanding, the World Health Organization and the International Fibre Safety Group agreed to collaborate and to promote the harmonization of methodology and of a worldwide quality assurance scheme in the evaluation of exposure to airborne health risk-related fibres in the work environment. The harmonization of methodology for the evaluation of exposure to health risk-related fibres will be covered in a document of Dr. Nigel P. Crawford of The Institute of Occupational Medicine Limited in Edinburgh. The present working document will review the existing national and international schemes with a view to compare them and to provide the basis for the recommendation of changes and, if possible, of determining the most suitable quality assurance scheme. The aim of the proposed quality assurance system is to harmonize internationally, to improve and to maintain improvements of fibre counting standards. In order to achieve satisfactory performance, a laboratory should establish an adequate quality control programme, in agreement with at least all the elements discussed in the **ANNEX-I**.

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A REFERENCE SCHEME FOR QUALITY ASSURANCE OF FIBRE COUNTS BY PHASE CONTRAST OPTICAL MICROSCOPY

1. INTRODUCTION

To identify the existing schemes for quality assurance, both national and international, a survey was conducted by the Health and Environment division of The Asbestos Institute during March and April 1992. The results of this survey and a review of the literature has made possible the analysis of the current scheme for quality assurance of fibre counts using phase contrast optical microscope.

The survey was restricted to 34 countries and should not be considered exhaustive. Some of the quality assurance schemes discussed may not have been published and in some of the pertinent papers, insufficient details were given to allow useful direct comparison. Internal and working documents with restricted distribution were often used to better understand the current quality control scheme which has been used as basis to develop a new quality assurance scheme.

To reach the objectives of a suitable international scheme, a quality assurance protocol should neither be too complex to avoid an unpractical scheme, nor too simplified, which would make relevant performance comparison impossible. The proposed quality assurance scheme is a compromise in many of its requirements, such as the number of samples per exchange, the number of rounds per annum, and mainly the whole statistical treatment of data where a normal (symmetric) distribution were assumed, as only a small percentage of the results will be found not to follow a symmetric distribution by random chance, as observed in many ongoing exchanges.

2. SURVEY OF NATIONAL AND INTERNATIONAL QUALITY ASSURANCE SCHEMES

The inquiry was initiated with a letter as the one shown in the **ANNEX-II** and mailed on 12 March 1992 to 57 experts of 34 different countries asking them to inform us of any existing national and international quality assurance schemes other than the following schemes already well known to us:

- RICE (Regular International Counting Exchange).
- AFRICA (Asbestos Fibre Regular Informal Counting Arrangement).
- INRS-FRANCE (Institut National de Recherche et de Sécurité-France).
- ACT-AIA (Asbestos Counting Trial, Asbestos International Association).
- PAT-USA (Proficiency Analytical Testing, United States of America).

A follow-up letter or a facsimile was sent on the 15th of April 1992 to remind those who did not answer the first letter. The cumulative and summary results of the enquiry can be found in the **ANNEX-III**. A reply was received from 54% of the contacted experts. It is reassuring to find that the experts who had not replied to the first letter, but did reply to the second letter, have generally informed us that they do not know any other quality assurance schemes than RICE, AFRICA, ACT-AIA and PAT-USA.

From our enquiry and the published quality assurance programmes, we have found the existence of eleven national quality assurance schemes.

- Australia: National Asbestos Programme (NAP) of NATA (1).

- Belgium: Asbestos Fibre Inter-laboratory Comparison: AFIC (2).

- Canada: Inter-laboratory Exchange (IE) of QAMA (3).

- Denmark: Asbest Interkalibrering (AI) from PAT (4).

- France: Asbestos Counting Quality Control Scheme (ACQCS) of INRS (5).

- Germany: Qualitatssichering bei der Faserzählung durch Ringversuche: QFR (6).

- New Zealand: NZ Quality Assurance Scheme (NZQAS) for TELARC (7).

- Portugal: National Quality Assurance (NQA) as RICE (8).

- Spain: Programma Interlaboratorios de Control de Calidad de Fibras de Amianto: PICC-FA (9).

- United Kingdom: Regular Inter-laboratory Counting Exchange: RICE (10, 11).

- United States of America: Proficiency Analytical Testing-Asbestos Analyst Registry (12).

Amongst these eleven national schemes, at least two of them have been classified as "international", because they have expanded to other countries:

- National Asbestos Programme, operated by the National Association of Testing Authorities Australia (1).

- Proficiency Analytical Testing-Asbestos Analyst Registry, operated by the American Industrial Hygiene Association (12).

The three other **international** quality assurance schemes covering many countries were:

- Asbestos Counting Trial, operated by the Laboratoire d'Hygiène et de Contrôle des Fibres Minérales for the Asbestos International Association (13).

- Asbestos Fibre Regular Informal Counting Arrangement (AFRICA), operated by the Institute of Occupational Medicine Ltd. (11, 14).

- WHO/EURO Man-Made Mineral Fiber Reference Scheme, run by the Institute of Occupational Medicine Ltd. on behalf of the World Health Organization Regional Office for Europe (15, 16).

3. COMPARISON OF RELEVANT QUALITY ASSURANCE SCHEMES

The fourteen relevant quality assurance schemes considered in this document can be roughly classified into four different groups of proficiency criterias:

GROUP I: Proficiency rating based on ranges of ratios of each count with the reference count as in the cases of:

- AFRICA (International).
- AFIC (Belgium).
- NQA (Portugal).
- RICE (United Kingdoms).

GROUP II: Proficiency rating based on ranges within confidence limits with the reference count as in the cases of:

- AI (Denmark).
- NAP (Australia).
- PAT-AAR (International).

GROUP III: Proficiency rating based on ranges within coefficient of variation of the reference count as in the cases of:

- NZQAS (New Zealand).
- PICC-FA (Spain).

GROUP IV: Proficiency rating based on ranges of ratios of each count with the reference count (inter-laboratory index) and on

coefficient of variation of the normalized results of each counter (intra-laboratory index) as in the cases of:

- ACQCS (France).
- ACT-AIA (International).
- IE-QAMA (Canada).
- QFR (Germany).
- WHO-EURO (International).

Most of the quality assurance schemes (Groups I, III and IV) are using **normalized results** which are proportions (or ratios) of individual or laboratory count to reference count to assess the performance limits. A proficiency rating can then be assigned from pre-defined ranges of normalized results. For some of the quality schemes (Group IV) an **inter-laboratory index** was obtained from the mean of ratios of each count with the reference count. An other asset of the quality assurance schemes within the Group IV is the use of the **coefficient of variation** of the normalized densities to obtain the **intra-laboratory index** which constitutes a second interesting criteria to evaluate the performance of laboratory's counts.

A different and valid statistical approach for inter-laboratory comparisons of counts is applied in the quality assurance schemes within the Group II, where confidence limits are used to compare individual counts with reference values, and then to rate the performance categories of the counts.

The performance limits and ratings of the counts of all the previously discussed quality assurance scheme are summarized in the **TABLE-A**.

4. PROPOSED QUALITY ASSURANCE SCHEME

After a detailed analysis and consideration of the implications of the existing quality assurance schemes, comparisons between the schemes were thoroughly studied. This has formed the basis for recommendations of a new quality assurance scheme for fibre counting (**TABLE-B**).

No single relevant quality assurance system appears to be fully satisfactory to provide a suitable quality assurance scheme to harmonize fibre counting standards internationally. As a first requirement, not met by many of the ongoing schemes, the frequency of test sample exchanges should not be less than every four months, as recommended by ISO/REMCO N 231 (17). The number of test samples per every 4 months exchange has been fixed to eight to ensure the statistical validity of the data (3 exchanges per annum). Participating laboratory should be organized and should follow the requirements for an appropriate quality system as in the ISO/IEC Guide (18).

4.1 Operational procedures of the scheme

General description

For each round, every 4 months, a batch of eight exchanges samples should be sent to participating laboratories. Each sample kit should be counted in time for participants to obtain repeat samples, if necessary, before the next round starts. Lab-data for that round should be analyzed to evaluate their performance according to the statistical protocol summarized in the **ANNEX-IV**.

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Exchange samples

A batch of the exchange samples to be counted by each participating laboratory should comprise four unmounted filters made of one laboratory blank filter and three filters from laboratory replicate aerosols samples prepared according to the generation procedure of the National Institute of Occupational Safety and Health (NIOSH) by Baron et al. (19). The remaining exchange samples should be formed of four mounted filters or slides (without blank) from field samples.

The following procedure should be applied before accepting the samples for distribution and assigning reference counts.

(1) Microscopical quality and fibre loading of every sample should be checked and counted by two independent, experienced qualified counters for even fibre distribution and proper density which should be within the applicability limits of the reference membrane filter method.

(2) The coefficient of variation of duplicate counts on replicate samples should not exceed 0.5 times the reference intra-laboratory index (CV). For an acceptable performance limit, the CV should be smaller than 40%.

(3) The reference count for a sample is derived from the mean count reported by laboratories rated "1" for that round. The reference count will be considered reliable if the geometric mean of the ratios of the counts from each laboratory rated "1" (for that round) to the reference count (mean of all reference laboratory counts) is within the range of 0.70 to 1.70.

Participation procedure (ANNEX-V)

Each participating laboratory should use its routine evaluating method, which may need to be validated to correct for a systematic bias in counts, to assess the performance of participants using a routine method not equivalent to the reference method. Each active analyst of a laboratory should count at least two samples in each round and not more than four analysts should participate in the same round. When a laboratory has more than four analysts, the analysts should take turns, so that eventually all analysts are evaluated after a certain number of rounds. Before each round, each laboratory is notified of the start and the order of circulation of the batch of samples so that all concerned laboratories know when to expect the samples.

One month later, the allocated batch of samples is dispatched by registered mail to the first laboratory of a group of laboratories formed of typically four laboratories located nearby. At the same time, instructions for the handling of samples, set of results forms and a circulation list are included. For each round, a batch of eight samples (4 filters and 4 slides) of different fibre types and densities are formed by the coordinating laboratory having at least one member on a small **steering committee of experts** in charge of the overall management of the quality assurance scheme.

After each round, an updated list of participants should be available and should list participating laboratories in a awaiting classification until a minimum of three rounds have been completed or according to their performance in the latest three rounds.

4.2 Evaluation of results of each round

Fibre densities results of each sample which have been counted only once by the participating counters of a laboratory should be returned by registered mail to the coordinating laboratory within a week on a return form of laboratory's counts (**ANNEX-VI**). Upon completion of a round with all available results, the fibre counts of each laboratory are statistically assessed for the current round based on an acceptable intra-laboratory index and on pre-defined performance limits.

The processing of results other than blank of the participating laboratories is as follows:

(1) For each sample, the **reference mean count (R)** is derived from the mean count of all the laboratories rated "1" for that round.

(2) For each sample, the **reference standard deviation** (σ_R) is obtained from the same counts previously used to calculate the reference mean count.

(3) The **Z-scores** should be derived for each reported count by taking the difference of the laboratory count (X) and the reference mean count (R) divided by the reference standard deviation (σ_R).

(4) For each round, the numbers of individual counts (X) of each laboratory should be classified in each of the ranges according to the inclusive performance limits which equal the reference mean value (R) ± 2 and ± 3 reference standard

deviation (σ_R) and, if otherwise, to the inappropriate performance limits.

(i) Inner limits: $R - 2\sigma_R < X < R + 2\sigma_R$

(ii) Outer limits: $R - 3\sigma_R < X < R + 3\sigma_R$

(iii) Inappropriate limits: $X \geq R + 3\sigma_R$ or $X \leq R - 3\sigma_R$

Then a percentage of total number of valid counts within each previous performance limits are calculated for that round.

For each round, individual blank count from a participating laboratory should be compared to the blank reference mean count of laboratories rated "1" with the other exchange samples for that round (**ANNEX-VII**). The difference of the individual laboratory blank count and the blank reference mean count should preferably be equal or smaller than 3 fibres. If the difference is greater than 3 but smaller than 5, it will be a borderline situation which may indicate contamination problem. Otherwise, with a difference greater than 5 fibres, immediate corrective action should be taken by the participating laboratory.

The evaluation report of laboratory counts for each round (**ANNEX-VIII**) should include:

- The reference mean value (R) of each sample.
- The reference standard deviation (σ_R) of each sample.
- The Z-score of each reported count.
- The numbers of individual counts within each of the performance limits (i), (ii) and (iii).

- The evaluation of blank count.

The preliminary evaluation report for a round is intended, as a rapid feedback of the performance to permit a laboratory early remedial action if needed.

4.3 Proficiency classification after three consecutive rounds

Participating laboratories should be classified upon performance over the current year. At the end of each round, the laboratory performance classification for the latest three consecutive rounds should be reported (**ANNEX-IX**) from pre-defined ratings:

(a) Rating of "1": if the proportion of individual counts in the inner limits (i) is ≥ 75%.

(b) Rating of "2": if, furthermore, the proportion of individual counts in the outer limits (ii) is ≥ 75%.

(c) Rating of "3": if otherwise or coefficient of variation (CV) ≥ 40%.

The performance limits (i), (ii) or (iii) measures how the individual count related to the mean reference count and is called **the inter-laboratory index.**

The coefficient of variation (CV) of the normalized values (obtained from ratios of laboratory counts to reference mean counts), for the latest three consecutive rounds, assesses the internal consistency of the laboratory and is called **the intra-laboratory index.**

Individual laboratory proficiency is classified as "**satisfactory**" if the arithmetic mean of the percentages of counts within the inner limits (i) is ≥ 75%.

Individual laboratory proficiency is classified as "**questionable**" if the arithmetic mean of the percentage within the outer limits (ii) is ≥ 75%.

Individual laboratory proficiency is classified as "**unsatisfactory**" if otherwise or if the coefficient of variation of the normalized values is ≥ 40%.

If a laboratory has not completed three or more rounds or has failed to submit results of the last round, this laboratory is classified as "**awaiting**" proficiency.

A laboratory classified as unsatisfactory should receive a notification by registered mail. A such "unsatisfactory" proficiency classification indicates serious analytical problems that need immediate corrective actions (**ANNEX-X**).

CONCLUSIONS

The proposed quality assurance scheme does not cover all details of regulatory and disciplinary procedures that will depend on management and administrative policies unknown to us at this stage.

This quality assurance scheme will assist laboratories to improve their performance of fibre counting standards and is intended to complement and not to replace the internal quality control programme of the participating laboratory. Even if the proficiency of a laboratory has been classified "satisfactory", it should not be warranted to tolerate inadequate situations identified by the internal quality control programme of the laboratory.

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TABLE-A

Comparison of Quality Assurance Schemes

Quality assurance scheme (country)	Number of samples per round	Statistical treatment of data	Satisfactory performance limits			Rating (single round performance)	
			Description	Lower	Upper	Rated	Description
RICE (United Kingdom)	8 (3-4 rounds/year)	R Ratio (X/R)	inner limits outer limits	0.65R 0.50R	1.55R 2.00R	1 2 3	≥ 75% of counts within limits ≥ 75% of counts within limits otherwise
		R Ratio (X/R)	inner limits outer limits	$(\sqrt{R} - 1.57)^2$ $(\sqrt{R} - 2.34)^2$	$(\sqrt{R} + 1.96)^2$ $(\sqrt{R} + 3.30)^2$	1 2 3	≥ 75% of counts within limits ≥ 75% of counts within limits otherwise
AFRICA (International)	8	R Ratio (X/R)	inner limits outer limits	0.70R 0.55R	1.70R 2.20R	1 2 3	≥ 75% of counts within limits ≥ 75% of counts within limits otherwise
ACQCS (France)	21	R Ratio (X/R) C V.	inter-lab. index: inner limits inter-lab. index: outer limits intra-lab. index	0.75R 0.50R with CV < 40%	1.33R 2.00R	1 2 3	mean of the normalised results within limits mean of the normalised results within limits otherwise or CV ≥ 40%
QFR (Germany)	≥12 (+ blanks)	R Ratio (X/R) C V	inter-lab. index intra-lab. index	- -	- -	- -	(mean of the normalised results X100)-100 CV of the normalised results
ACT-AIA (International)	15	R Ratio (X/R) C V	inter-lab. index: inner limits inter-lab. index: outer limits intra-lab. index	0.75R 0.50R inner CV < 30% & outer CV < 50%	1.25R 1.50R	1 2 3	mean of the normalised results within limits and CV < 30% mean of the normalised results within limits and CV < 50% otherwise
WHO/EURO (International)	8	R Ratio (X/R)	inner limits outer limits inter-lab. index intra-lab. index	0.70R 0.50R - -	1.40R 2.00R - -	1 2 3 - -	≥ 75% of counts within limits ≥ 75% of counts within limits otherwise (mean of the normalised densities X100)-100 CV of the normalised densities
NAP (Australia)	6 (2 rounds/year)	R σ	inner limits outer limits	R - 2 σ R - 3 σ	R + 2 σ R + 3 σ	0-2 3 4	0 - individual slides : satisfactory 1 - individual slides : straggler 2 - individual slides - otherwise: : outlier

X = Individual count

R = Reference count

C V = Coefficient of variation

σ = Standard deviation given by $\sqrt{m + 0.04\ m^2}$ (Ogden's work)

σ_R = Standard deviation of reference laboratories values

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Comparison of Quality Assurance Schemes

Quality assurance scheme (country)	Number of samples per round	Statistical treatment of data	Satisfactory performance limits			Rating (single round performance)	
			Description	Lower	Upper	Rated	Description
NQA (Portugal)	-	See RICE (U.K.)					
PICC-FA (Spain)	16	R C V	± 35% of the reference value	0.65R	1.35R	C NC	≥ 75% of counts within limits otherwise
AFIC (BELGIUM)	8 (3 X 8 = 24)	$\bar{X}$, GM, 1988 R, Ratio (X/R) 1992 N.R. 1992→	inner limits outer limits see RICE	0.60R 0.50R	1.80R 2.00R	1 2 3	≥ 75% of counts within limits ≥ 75% of counts within limits otherwise
PAT-AAR (AIHA) (U.S.A.)	4 (4 times/year)	$\bar{R}$ (From reference σ_R transformed Z-Score values)	performance limits	$\bar{R} - 3\sigma_R$	$\bar{R} + 3\sigma_R$	acceptable outlier	≥ 75% of counts within limits for 4 last consecutive rounds or 100% of counts within limits for 2 last consecutive rounds otherwise
NZQAS (New Zealand)	-	R C V	± 30% of the reference value	0.70 R	1.30 R	acceptable outlier	all counts within limits otherwise
AI (Denmark)	4	$\bar{X}$ σ See PAT-AAR					
IE (Canada)	8 (2 times/year)	R Ratio (X/R) C V	inter-lab. index: inner limits / outer limits intra-lab. index	0.65R / 0.55R inner CV < 25% & outer CV < 45%	1.70R / 2.20R	1 2 3	mean of the normalised results within limits and CV < 25% mean of the normalised results within limits and CV < 45% otherwise

$\bar{X}$ = Arithmetic mean

GM = Geometric mean

N.R. = Normalised results

$$\text{Z-Score} = \frac{X - R}{\sigma_R}$$

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TABLE-B

PROPOSED QUALITY ASSURANCE SCHEME FOR FIBRE COUNTING

Total number of samples for 3 rounds per annum	Statistical parameters	Performance limits				Proficiency rating
		Description	Lower	Upper	Rated	Laboratory classification
21 (without blanks)	Reference mean count (R)	Inner limits	$R - 2\sigma_R$	$R + 2\sigma_R$	1	"Satisfactory" if 75% of counts are within limits and CV < 40%
	Reference standard deviation (σ_R)	Outer limits	$R - 3\sigma_R$	$R + 3\sigma_R$	2	"Questionable" if 75% of counts are within limits and CV < 40%
	Inter-laboratory index (rating of 1, 2 or 3)	Outlier	$X \leq R - 3\sigma_R$	$X \geq R + 3\sigma_R$	3	"Unsatisfactory" if otherwise
	Intra-laboratory index (CV)		or CV ≥ 40%			

ANNEX-I

ELEMENTS OF A QUALITY CONTROL PROGRAMME

ELEMENTS OF A QUALITY CONTROL PROGRAMME

The first essential step of a quality control programme is the creation of a quality control manual with at least the following sections:

- Laboratory policy.
- Administration of quality control programme.
- Description of facilities and equipment.
- Calibration of equipment.
- Analytical methods.
- Intra-laboratory validation procedure.
- Inter-laboratory validation procedure.
- Recording of results.
- Writing reports.

To facilitate the understanding and the coherence of the different elements for an adequate quality control system, the steps listed in the attached **FLOW-CHART A** will be followed. This flow-chart is divided into three sections which correspond to the three main stages for sample evaluation with the reference membrane filter method for fibre counts:

1. Sampling.

2. Mounting.

3. Counting.

1. SAMPLING

1.1 Monitoring method and strategy

Only standard testing techniques relevant to fibrous dust sampling should be used to monitor the employee exposures. Proper evaluation of airborne health-related fibres necessitates adequate monitoring strategies for valid exposure measurements. The use of statistical concepts as the one outlined in the NIOSH's occupational exposure sampling strategy manual by Leidel et al. (1977)[1] is necessary because of some unavoidable random measurement errors.

1.2 Filter verification

1.2.1 Filter contamination

Each new lot of filters should be checked before it is used. Take four filters per box of one hundred or one per package of twenty-five. In each of the packages in a box, the filter should be chosen from namely the first fourth, the second fourth, the third fourth and the last fourth, respectively. These are considered as the laboratory blanks. Discard the lot of filters if any one of the filter is greater or equal to 5 fibres per 100 graticule fields counted. The lot of filters should be returned to the manufacturer. A written log or record of blank values, filter lot numbers should be kept.

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1.2.2 Filter area

Each new lot of filter holders should be checked to determine their effective filter area. Four diameters of each two filter holders randomly chosen in a box of fifty should be measured within ±0.1 mm according to a reference method. The arithmetic mean of the measured diameters provides a satisfactory estimate of the filter diameter to calculate in the usual manner the effective filtration area of the filter holder.

1.3 Calibration of equipment

All equipment should conform to the requirements of the reference method. There should be periodic maintenance of the equipment to ensure that it operates properly.

1.3.1 Calibration of the bubble burette

The class "A" 1 litre burette should be calibrated on a yearly basis to check that the burette volume is maintained within ±0.2% when used at the prevailing conditions of room temperature and pressure for the calibration of sampling pump flow rate.

1.3.2 Calibration of the sampling pump flow rate

Each sampling pump should be calibrated within ±5% accuracy. A primary standard calibration device (e.g. spirometer, aspirator bottle or soap bubble burette) is necessary to calibrate the sampling pump flow rate. One accurate and commonly used primary calibrator for

personal sampling pump is the soap bubble burette. An accurately checked stopwatch (±0.1%) and a pre-calibrated bubble burette should be used for the calibration of the sampling pump flow rate that should be checked before and after each sampling period. A manometer should be installed between the primary calibrator and the flow meter attached to the sampling pump to determine the gas pressure. The temperature and the barometric pressure should be recorded.

Re-calibration of the pump flow rate is essential if it is operated under conditions substantially different from those of calibration. "Substantial" implies a difference in altitude or temperature by more than 500 m (~38 mm-Hg) or 15°C respectively compared to the calibration conditions.

1.4 Pre-sampling checking

Before sampling, the battery capacity of the pump should be sufficient to operate continuously over the chosen sampling time. The flow should be free from pulsation. Connecting tubing should be constriction-proof and the connections leakproof. The flow rate should be checked with an external calibrated flowmeter as soap bubble meter to an accuracy within ±5% of the true flow (95% confidence limits) and a filter from the same lot as the one used for the samples collection.

1.5 Field blank

For each series of samples, submit at least two blanks or 10% of the total samples, whichever is greater. A field blank should be

collected in exactly the same manner as an air sample except that no air should have been drawn through the filter. If one of the field blanks has a fibre level greater than 7 fibres per 100 graticule field, note a possible contamination of the samples.

NOTE: The identity of the blank must remain unknown to the counter until the counts have been completed.

1.6 Sampling conditions for proper quantification

All sampling conditions should be noted from ambient conditions (temperature, relative humidity and atmospheric pressure) to working and control methods (ventilation, working habit, respirator, cleaning and other working conditions). Knowledge of ambient conditions may be required to allow correction of the sampling flow rate. Working methods or conditions may explain abnormal situations that should be corrected.

For a proper quantification of the airborne fibres, an appropriate sampling strategy should be followed and the sample loading should be within the limits of quantification of the sampling method.

1.7 Post-sampling checking and calibration of pumps

The calibration of the pump should be checked after each sampling period, usually at the end of the sampling day, with a primary standard as a soap bubble meter and a manometer as required in the calibration procedure of the pump flow rate. The mean flow rate (before and after the sampling period)

should be used with the exact sampling time to calculate the sampled volume. Under substantially different conditions between the sampling and the calibration conditions, appropriate corrections for temperature and pressure may be essential if a re-calibration of the pump flow rate was not performed at the sampling site.

1.8 Chain of custody (from sample identification to storage)

A system for sample logging is required to determine the personal, material and instrument being involved in all the sample tracking. The sample identification number should allow cross-referencing to follow the sample from the manufacturer to the end results. The hand-entry logbooks should note appropriate manufacturer filter lot number, laboratory number, field number, analysis number and other identifying numbers with all suitable information to ensure proper follow-up of the sample.

1.9 Shipping and reception of samples

Samples should be transported or shipped in their sampling holders with conductive cowl attached, top cap or cover fitted. A rigid and clean container should be used to prevent damage. Untreated polystyrene foam should not be used in shipping container because of the possibility of fibre loss from sample filter due to electrostatic forces.

Sample holders should be cleaned (using a high efficiency vacuum or wet cleaning) before to bring them in the mounting and counting laboratory.

Paperwork accompanying the samples should be checked and sample identification numbers should correspond to those of the sampling information.

2. MOUNTING

2.1 Preparation method

Use only permanent mounting technique as described in reference preparation methods for the determination of airborne fibres at workplaces by phase contrast microscopy.

2.2 Cleaning slides and equipment

Clean conditions to avoid contamination should be maintained at all times. Routinely monitor the selected clean room for filter handling. If contamination is found, the source should be eliminated. Clean non-contaminated clothing should be worn to enter the clean room, whose access should be limited to as few personnel as possible. All samples and equipments should be cleaned and decontaminated before being brought into the clean room. Laboratory blanks should be analyzed to check and eliminate problems of contamination as early as possible. Clean all mounting materials (slide, cover slip, scalpel, forceps) with lens tissue to ensure that the surfaces are free from contamination.

2.3 Blanks

Handle sufficient blanks in the same fashion as the field samples. The number of blanks should represent at least 10% of the total samples number or a minimum of two blanks.

2.4 Filter sample cutting

Mounting of the total filter is recommended. If it is required to cut the filter, all cutting should be done with a scalpel using rolling action. Scissors should not be used. Not less than one quarter of the filter should be cut wedge-shaped prior to clearing.

2.5 Analysis Identification number

As part of any quality control scheme, a new identification number should be given to the sampling filters to be analyzed. This new number will be the **analysis identification number**, which should be marked on the corresponding slide and used to identify the mounting filters.

2.6 Clearing the filter

Analytical reagent grade should be used for clearing of the sampling filters. When the filters have been exposed to high humidity, clarity may be improved by drying them before clearing. Precautions particular to toxicity and flammability of the reagents should be followed.

2.7 Adjusting the refractive index

Because of the possibility to collect different fibre types, the refractive index of the fibres must be known or at least classified within a range that will allow the choice of the proper reference mounting technique. The mounting reagent should be analytical

reagent grade, fibres free and of a periodically checked refractive index. A micropipette should be used to add no more than 10 µl of the proper refractive index mounting reagent when a total filter has been cleared to prevent excessive overflow round the edges. Do not press the cover slip onto the filter when the cover slip is lowered at an angle onto the filter.

2.8 Finishing the clearing of the slide

To overcome the granular appearance of the newly mounted filter which affects the counting it is recommended to leave the slide at room temperature for 24 hours or to heat the slide for 15 minutes at 50°C before counting.

2.9 Sealing the slide

To improve the long term keeping quality of the slide it is recommended to paint round the edges of the cover slip with a microscopical embedding agent.

2.10 Storage of the slide

It is desirable to store the slides flat to attenuate the migration of fibres on the slide. The mounted slide can be stored for a maximum of two year without significant or noticeable deterioration, although some small-scale fibre movement can occur.

3. COUNTING

3.1 Analytical method

For the evaluation of exposure to airborne health risk-related fibres in the work environment, the fibres should be sized and counted using a phase contrast microscope according to some rigorous counting criteria as defined in the reference membrane filter method for workplace.

3.2 Equipment and facility requirements

Microscope equipments should be in accordance with the specifications given in the reference analytical method for optical fibre counts. The equipment adjustment and calibration as specified in the manufacturer's instructions and the reference membrane filter method should be performed. Periodic servicing is needed, at least once a year, to ensure that equipment is kept in proper working condition.

At least once a day and each time a counter uses an other microscope, the following steps should be taken before a fibre count may begin:

(1) Adjust the microscope.

(2) Calibrate the eyepiece graticule with a standard micrometric slide having divisions of at least 0.01 mm.

(3) Verify the microscope's limit of detection with an HSE/NPL test slide.

The previous information should be continually updated in a laboratory equipment information register.

The accuracy of fibre counts may be influenced systematically by the working environment. The counting laboratory should be free of dust and maintained under positive pressure if there is a possibility of fibrous dust contamination. Counters must have comfortable, adjustable chairs for proper adjustment of height and support. Counters should take a break from counting after every hour. Counters requiring corrective lenses for astigmatism should perform counts using their corrective lenses.

3.3 Microscope/counter performance assessment

The HSE/NPL test slide should be used daily, to assess the microscope/counter performance prior to analyzing samples and re-checked each time there is a change in counters, oculars, objective or graticule. The test slide contains seven blocks, each containing twenty ridges, separated by gaps of 20 micrometers. Each block of ridges becomes progressively fainter as one scans from left to right across the test slide. With a good microscope set up correctly, blocks 1 through 3 must be clearly visible and blocks 4 and 5 at least partially visible. A block of ridges is defined as being visible when all ridges of the block can be clearly seen for their entire length between the horizontal marker ridges. If these criteria are not met, counting should not be performed as the microscope resolution is unacceptable for fibre counting.

To ensure that valid results are being generated, the counter should participate in recognized inter-laboratory exchanges of samples, and should pass their minimum statistical requirements. The counter who has successfully participated in at least three consecutive rounds of exchanges involving at least

6 samples per exchange will become a validated counter. Validation will be maintained if he continues to meet all the requirements of the "intra" and "inter" laboratory validation programme.

3.4 Counter training

The counter should be trained under the supervision of a validated counter until his coefficient of variation is less than or equal to experienced counters or to that of the laboratory as determined by appropriate statistics. If the laboratory's coefficient of variation is not known, it may be established at 45%. For example, a laboratory might require performance within two standard deviations of the intra-laboratory mean of previous results for these samples. Corrective action should be taken, as necessary, to improve performance to an acceptable level. As part of his training, the counter should have learned at least the following:

- Analytical method principles.
- Microscope requirements and adjustments.
- Eyepiece graticule calibration.
- Microscope/observer performance observer.
- Counting criterias.
- Quality assurance practices.
- Calculation of results.
- Statistical evaluation for data comparison.
- Data recording and keeping.
- Limitations of the method.

New counters should be provided with the above training and each segment of the training should be signed off by the trainee and trainer when completed. As a last step of the training programme, the analyst must analyze at least 20 reference

samples (samples well characterized by multiple counts by experienced counters). The entire training programme should be completed before the analyst begins to report results. Participation in a formal training course in fibre counting by optical microscopy is recommended, but can only form a **portion** of the required training programme.

3.5 Quality assurance programme for fibre counts

In addition to regulating the competence of personnel, equipment and facility requirements and the use of appropriate analytical methods, a quality control assurance programme for fibre counts should be maintained. The principal elements of a programme verifying analytical results are:

- The intra-laboratory validation procedure.
- The inter-laboratory validation procedure.

3.5.1 Intra-laboratory validation procedure

The primary elements of the intra-laboratory validation procedure are:

- Microscope verification.
- Blank filter verification.
- Control filter verification (minimum 2 control filters for each series of filter samples taken in a single day).
- Reference sample count.
- Blind sample recount (minimum 1 blind sample per day of counting or 10% of the analyses of a single series of samples counted during a single counting day).

- Comparison of microscopes if counter uses more than one.

3.5.1.1 Microscope verification

- Adjust microscope (at each slide).
- Calibrate reticule (daily).
- Verify limit of detection (daily).
- Clean and service microscope (at least annually and when required).

3.5.1.2 Blank filters

Consult the current reference analytical method. Verify at least one filter per package of 25 filters. Fibre density should be less than or equal to 3 fibres per 100 fields observed.

3.5.1.3 Control filters

Consult the reference analytical method. Verify at least two unused filter in each series of filter samples taken in a single day. Fibre density should be less than or equal to 5 fibres per 100 fields observed.

3.5.1.4 Reference sample

Verify at least five permanently prepared reference samples representative of the determination done at the laboratory. At least one reference sample should be verified every

day of analysis. Reference samples are counted to help determine the laboratory's coefficient of variation ($C.V._{LAB}$), which should be less than 25%.

3.5.1.5 Blind recount

At least 10% of the samples analyzed should be recounted by the same counter after the slides have been renumbered so they cannot be recognized. The difference between the square roots of the two counts in fibre/mm^2 ($\sqrt{x_1} - \sqrt{x_2}$) must not exceed 2.77 times the average of the square roots of the two fibre counts in fibre/mm^2 multiplied by one half of the intra-laboratory's coefficient of variation (s_r).

$$|\sqrt{x_1} - \sqrt{x_2}| \leq 2.77 \frac{\frac{\sqrt{x_1} + \sqrt{x_2}}{2}}{2} s_r$$

3.5.1.6 Microscope comparison (if necessary)

Compare at least two blind recounts per series of samples analyzed and taken from the same counting day. The difference between the two recounts D must be less than or equal to 0.25 times the average of the two recounts $\bar{F}$.

$$D \leq 0.25 \quad \bar{F}$$

3.5.2 Inter-laboratory validation procedure

To maintain performance, a laboratory should participate successfully in at least three exchanges per year, involving at least six samples per exchange with at least two other analysts from two other laboratories. The analyst may, of course, be part of a pre-determined inter-laboratory exchange system that involves a greater number of analysts. This would, usually, make it easier for him to meet the minimum statistical requirements for remaining an accredited analyst.

3.6 Recording of data

There must be an established data recording system which contains the following details:

(1) Title.

(2) Date.

(3) Name of analyst (counter) and signature.

(4) Analytical method.

(5) Specifications and calibrations.

(6) Data.

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(7) Quality assurance programme.

(8) Calculations.

(9) Findings.

(10) Comments.

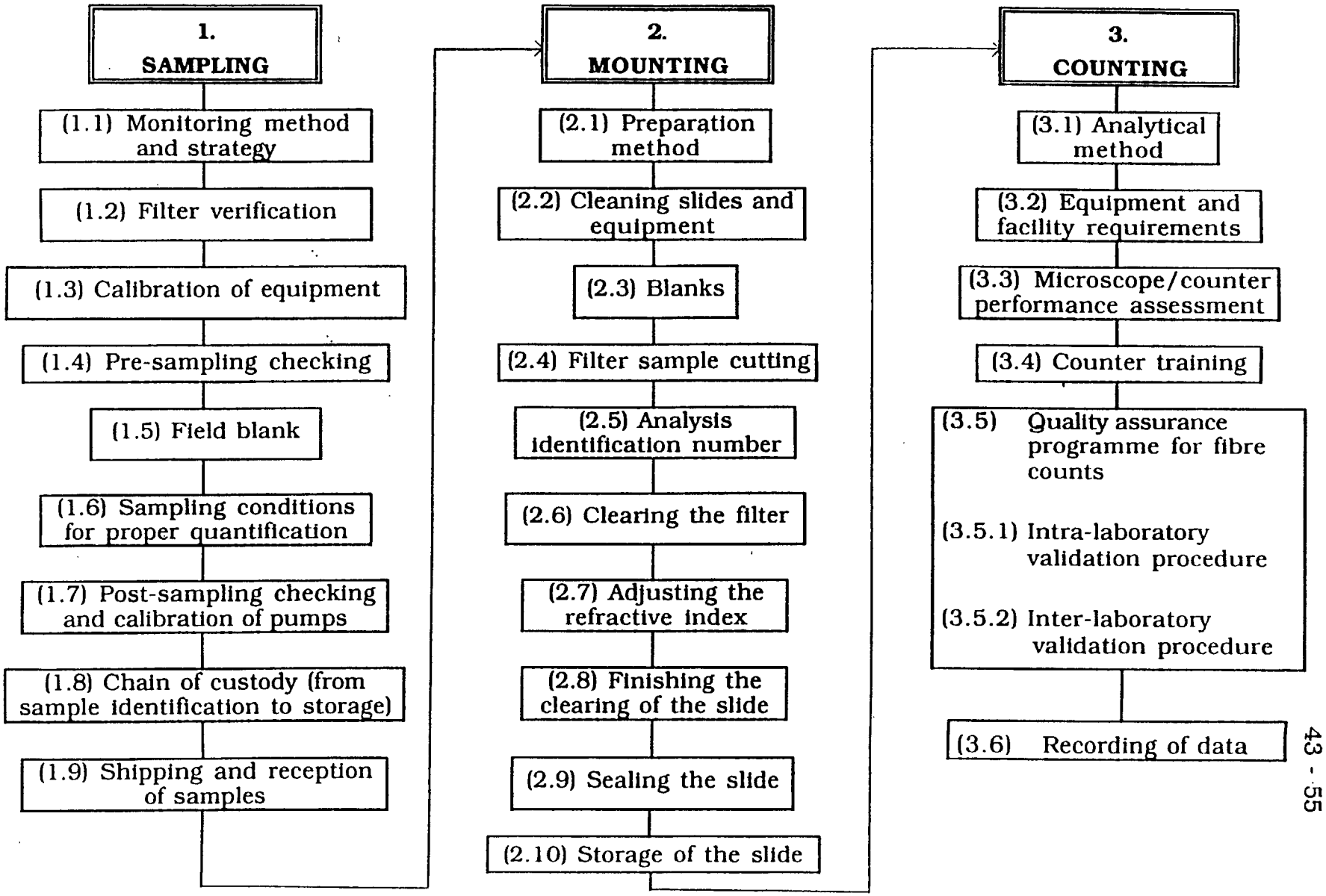
(11) References.

(12) Appendices (counting and calibration sheets, etc.).

All data must be preserved in complete and easily accessible files for the time period stipulated under current regulations. Whenever possible, data must be preserved for at least thirty years.

FLOW-CHART A

QUALITY ASSURANCE FLOW-CHART SYSTEM WHEN USING MEMBRANE FILTER METHOD



THE ASBESTOS
INSTITUTE

Sherbrooke, March 12, 1992

Dear Mr.:
Dear Mrs.:

Pavillon Marie-Victorin
Suite 336
Sherbrooke University
Sherbrooke, Québec
Canada J1K 2R1
Telephone: (819) 821-7633
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The working group of the WHO/IFSG for harmonization of methods and quality assurance in the evaluation of exposure to airborne fibres in work environment asked me, at the first planning meeting on 2-4 March 1992 in Geneva, to identify the existing national and international reference schemes for the quality assurance of fibre counts. These schemes will be analyzed in all their details and will be compared with a view to propose modifications, if necessary, and to determine the most suitable ones.

Could you, please, inform us, of any existing national and international quality assurance schemes (other than RICE, AFRICA, INRS-FRANCE, AIA and PAT-USA). I would appreciate very much to receive before the 15th of April 1992 the documents with all details (including statistical treatments of data) of the quality control program being part of your membrane filter method and of your national schemes, if any, or at least the name of the persons to be contacted for further information about your quality assurance schemes.

Thank you very much for your cooperation, and kind regards.

Jacques LeBel
Assistant Director
Health and Environment
JL/lc
c.c. Mr. Jacques Dunnigan

ANNEX-III

Country	Number contacted		Number of answers	National scheme		Description
	Letter	Fax		No	Yes	
AUSTRALIA	4		3		NATA	
BELGIUM	3		3		Belgium Ministry of Labour	
BRAZIL	2		2	X		
CANADA	2		1		QAMA	
CHILE	1		0	X		
COLOMBIA	2		1	X		
COSTA RICA	1		1	X		
CZECHOSLOVAKIA	1		1	X		
DENMARK	1		1		Filters from PAT	
EGYPT	1		0			
GERMANY	4	3	2		QFR	
HONG KONG	3	1	2	X		
HUNGARY	1		0			
INDIA	2		1	X		
IRELAND	1	2	1	X		
ITALY	2		1	X		
JAPAN	2		1	X		
KOREA	1		1	X		
MALAYSIA	1		0			
MEXICO	1		0			
NETHERLANDS	2		0			
NEW ZEALAND	1		1		TELARC	
PERU	1		0			
POLAND	2		0			
PORTUGAL	1		1		NQA as RICE	
RUSSIA	1		0			
SOUTH AFRICA	2		1	X		
SPAIN	2	1	1		PICC-FA	
SWITZERLAND	1	1	0			
TAIWAN	1		0			
THAILAND	1		1	X		
TURKEY	1		1	X		
UNITED KINGDOM	2	1	1		RICE	
U.S.A.	3	1	2		PAT-AAR (AIHA)	

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Organism	International scheme in 1991		Description
	No	Yes	
AIA		Asbestos Counting Trial (LHCF)	
AIHA		PAT-Asbestos Analyst Registry	
CEC	X		
IOM		Asbestos Fibre Regular Informal Counting Arrangement (AFRICA)	
NATA		National Asbestos Programme	
WHO		WHO/EURO	

ANNEX-IV

STATISTICAL PROTOCOL FOR EACH ROUND

In evaluating laboratories performance, the following steps are involved for each round. The blank count should be excluded of this statistical protocol.

(1) **Identification number.** An identification number must be assigned to each round, batch of samples, laboratory and group of laboratories.

(2) **Reference mean count (R).** For each exchange sample, the reference mean count must be derived from the mean counts of laboratories rated "1" for that round. The reliability of the reference mean count is checked from the geometric mean of the ratio of each count of laboratory rated "1" to the reference count which must be within the range of 0.70 to 1.70.

(3) **Normalized results.** The ratio of an individual laboratory count to the reference mean count is used to find the normalized mean of each laboratory.

(4) **Intra-laboratory index.** The coefficient of variation of the normalized results of each laboratory must be derived to assess the internal laboratory consistency or intra-laboratory index.

(5) **Reference standard deviation (σ_R).** For each exchange sample, the reference standard deviation must be derived from the mean counts of laboratories rated "1" for that round.

(6) **Z-score.** For each laboratory's count a Z-score must be calculated. The Z-score is the difference of the individual laboratory's count (X) and the reference mean count, divided by the reference standard deviation.

$$Z = \frac{X - R}{\sigma_R}$$

(7) **Performance limits.** The percentage of total number of valid counts is calculated for each of the following performance limits:

(i) Inner limits: $R - 2\sigma_R < X < R + 2\sigma_R$

(ii) Outer limits: $R - 3\sigma_R < X < R + 3\sigma_R$

(iii) Otherwise: $X \geq R + 3\sigma_R$ or $X \leq R - 3\sigma_R$

ANNEX-V

PARTICIPATION PROCEDURE

(1) One month before the start of the first or the next round, the coordinating laboratory should notify each participating laboratory of the order of circulation within its group of laboratories that will exchange the same batch of samples for that round.

(2) The coordinating laboratory should dispatch the batch of samples to the first laboratory in each group with a set of results forms, the instructions for the handling of sample and a circulation list.

(3) The laboratory will mount their allocated four filters within a few days of receipt according to their routine preparation technique.

(4) The whole set of allocated eight slides should be distributed evenly, amongst the active counters of the participating laboratory. Each counter should count at least two samples in each allocated batch of samples that should not be counted more than once by the same laboratory. When a laboratory has more than four counters, the remaining counters of the laboratory will be asked to evaluate the samples of subsequent rounds to eventually include all the counters.

(5) The laboratory should dispatch by registered mail the batch of samples (without the newly mounted filters specifically allocated to each laboratory) within seven days, to the next participating laboratory or to the coordinating laboratory for the fourth participating laboratory.

(6) The completed results forms of the participating laboratory should be sent by registered mail so that results are received by the coordinating laboratory, within ten days of the last evaluation. Late submitted results may not be processed and the laboratory will be classed as "awaiting classification" till the next round. If results can not be processed for two consecutive rounds for any reasons and without justification (as holidays or sickness) which should be submitted to the coordinating laboratory by registered mail, the laboratory should be suspended from the quality assurance scheme.

(7) Within fifteen days, at the end of each round, the coordinating laboratory should submit to each participating laboratory a report of their performance for the round and of their updated proficiency for the latest three rounds.

ANNEX-VI

RETURN FORM OF LABORATORY'S COUNTS

Laboratory name: _____ Laboratory no.: _____

Round no.: _____ Group no.: _____

Evaluation date: _____ Batch no.: _____

Microscope's magnification: _____

Type of graticule: _____

Mounting technique: _____

Counting criteria: _____

Number of counters for this round: _____

Number of counters in your laboratory: _____

Sample no.	Slide no.	Field area (mm^2)	Number of fibres	Number of fields	Fibre density (f/mm^2)	Comments

ANNEX-VII

EVALUATION OF BLANK'S COUNT FOR EACH ROUND

The blank's count for each participating laboratory must be considered outside of the whole statistical protocol used for the other samples of each round. The evaluation of the blank's count must be included to a laboratory's preliminary report, as a rapid feedback, for remedial action if needed.

(1) **Blank's reference mean count (R_B).** For each exchange blank, the reference mean count must be derived from the mean count of laboratories rated "1" with the other exchange samples for that round.

(2) **Maximum allowable blank's count.** The difference of the individual blank's count (X_B) and the blank's reference mean count (R_B) must be classified within the following limits:

(i) Inner limits: $X_B - R_B \leq 3$ "Acceptable"

(ii) Outer limits: $3 < X_B - R_B \leq 5$ "Borderline"

(iii) Otherwise: $X_B - R_B > 5$ "Unacceptable"

ANNEX-VIII

EVALUATION REPORT OF LABORATORY'S COUNTS FOR EACH ROUND

Date: _____

Laboratory name: _____ Laboratory no.: _____

Round no.: _____ Group no.: _____

Evaluation date: _____ Batch no.: _____

Sample no.								
Slide no.								
Lab. count (f/mm^2), X								
Ref. mean count (f/mm^2), R								
Ref. standard deviation (f/mm^2), σ_R								
Normalized results								
Z-score								

Mean of normalized results: _____

Intra-laboratory index (CV): _____

Performance limits of valid counts	% of counts within limits	Provisional classification (1)
$X \leq R - 3\sigma_R$		
$R - 2\sigma_R < X < R + 2\sigma_R$		
$R - 3\sigma_R < X < R + 3\sigma_R$		
$X \geq R + 3\sigma_R$		

Performance limits of blanks Acceptable ☐ Borderline ☐ Unacceptable ☐

NOTE (1): "Awaiting" classification: no result was submitted in time.
"Satisfactory" classification: at least 75% of counts (X) are within three reference standard deviation (σ_R) of the reference mean count (R).
"Unsatisfactory" classification: otherwise or CV ≥ 40%.

ANNEX-IX

REPORT OF LABORATORY PROFICIENCY CLASSIFICATION

Date of proficiency's evaluation: _____

Laboratory name: _____ Laboratory no.: _____

Round no.: _____ Group no.: _____

Description	Results																				
Sample no																					
Lab. count (f/mm^2), X																					
Ref. mean count (f/mm^2), R																					
Ref. stand. dev. (f/mm^2), σR																					
Normalized results																					
Z-score																					

Mean of normalized results: _____

Coefficient of variation (%): _____

Performance limits	% of valid counts within limits	Rating	Classification
$X \leq R - 3\sigma R$			
$R - 2\sigma R < X < R + 2\sigma R$			
$R - 3\sigma R < X < R + 3\sigma R$			
$X \geq R + 3\sigma R$			

Rating of "1": "Satisfactory" Proficiency. At least 75% of counts (X) are within two reference standard deviation (σR) of the reference mean count (R) and CV < 40%.

Rating of "2": "Questionable" Proficiency. At least 75% of counts (X) are within three reference standard deviation (σR) of the reference mean count (R) and CV < 40%.

Rating of "3": "Unsatisfactory" Proficiency. Otherwise.

No rating: "Awaiting" Proficiency. Results were not submitted in time or less than three rounds are completed.

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ANNEX-X

REMEDIAL ACTION

One of the aims of the quality assurance scheme is the improvement of the analytical performance of participating laboratories.

A laboratory classified as "questionable" after three consecutive rounds should investigate and correct internal analytical problems before the next round. If necessary, extra samples may be requested by the participating laboratory to help in this investigation.

A laboratory classified as "unsatisfactory" will receive notification with recommendations and a new batch of samples to be evaluated before the start of the next round. Repeated failure is a clear indication that further remedial actions should be taken (e.g. laboratory's audit, investigation of internal quality control programme, re-training of counters, ...). This laboratory will be classified in a "awaiting" situation for the next three exchanges that could be arranged, in particular, with the coordinating laboratory within a shorter delay than the one-year delay required for the regular three rounds.

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$$\frac{.001\ mg}{Vol/1000} = mg/m^3$$

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G7502	11 x 8½	2	Yes	10,000,000
G7504	" "	4	"	"
G7506	" "	6	"	100,000
G7507	" "	7	No	10,000,000
G7508	" "	8	"	100,000
G7512	11 x 16⅜	12	Yes	10,000,000
G7513	" "	13	"	"
G7514	" "	14	No	"

Punched 7 holes on 11-inch edge for Ring Binders with 3 or 7 rings.

GREEN COLUMNAR WORK SHEETS WITH COVERS

Stock Number		Sheet Size	Columns	Description Space	Units per Column
Padded	"Wyring" Bound				
G7602	WG7602	8½ x 14	2	Yes	10,000,000
G7603	WG7603	" "	3	"	"
G7604	WG7604	" "	4	"	"
G7605	WG7605	" "	5	"	"
G7606	WG7606	" "	6	"	1,000,000
G7607	WG7607	" "	7	No	10,000,000
G7606B	WG7606B	10½ x 14	6	Yes	"
G7607B	WG7607B	" "	7	"	"
G7608B	WG7608B	" "	8	"	1,000,000
G7610	WG7610	14 x 8½	10	"	"
G7612	WG7612	" "	12	"	"
G7613C	WG7613C	" "	13	"	"
G7613	WG7613	" "	"	No	"
G7613A	WG7613A	17 x 11	"	Yes	"
G7616A	WG7616A	" "	16	"	"
G7616	WG7616	" "	"	No	"
G7611	WG7611	17 x 14	11	Yes	10,000,000
G7612A	WG7612A	" "	12	"	"
G7614A	WG7614A	" "	14	"	1,000,000
G7614	WG7614	" "	"	No	10,000,000
G7618		25½ x 14	18	Yes	"
G7621		" "	21	No	"
G7625		34 x 14	25	Yes	"
G7630		" "	30	"	1,000,000

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Prepared By		
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Method #	contaminant		Abbreviation	(Analysis) Units to computer	Result in Units	PEL/TLV	Mol wt	Calculations
1 ✓	Formaldehyde	✓	F	ppm	ppm	O = 3ppm T6 = 1.0 ppm N = 1.0 ppm O=1ppm (2/82)	30.03	((Analysis - Blank) /1000) / Vol * 815.85 ✓
✓A	✓ - Impinger	✓						
✓B	✓ - ORBO-22	✓						
✓C	✓ - Protek	✓						protek only: Result = Analysis
D	CEA							
E	13X Mol Sieve							
✓F	✓ - ORBO-24	✓						Same as 1A
✓G	✓ - 3M Badge	✓						Same as 1A (.0614 diffusion rate)
2	Fiberglass		FG	fiber/field	fiber/cc	N = 3 fibers T6: 0.1 (before 84 Rule) Old - ((Analysis / Fields) - Blank) * 355) / (.03 * Vol * 1000) 0.1 (after 84 Rule) NEW ((((Analysis / 2) / Fields) - Blank) * 385) / .00785 * Vol * 1000		
A	CEF 37mm	✓		Mod. A Rule				
B	CEF 25mm	✓						
C	CEF 37mm		E	CEF 37(E)	E. Excavation (Only Jan 5/7/79)			((Analysis / Fields) - Blank.) * 355) / (.03 * Vol * 1000)
D	Silver Filter		E	mg	mg/m3	M 5 mg/m3		(Analysis - Blank) / (Vol / 1000)
✓ E	CEF 25mm			8.3 Rule		((Blank/2)/100)?		mg
3	Dust			mg	mg/m3	Benzene 2B		(Analysis - Blank) / (Vol / 1000) ✓ = mg/m3
A	PVC Total	✓	TD	0		O = 15 mg/m3 T6 = 5 mg/m3 O = 3 mg/m3 T6 = 1 mg/m3		
~~B~~	~~PVC Respirable~~	✓	~~RD~~	see 120A				
D	Teflon Total		TD					
C	Matched wt CEF		TD					
E	Glass fiber (F) 6F/5m		TD	(G) NATSCOS PVC pre-weighed filter				
4	Phenol		P		ppm	O = 5ppm	94.11	(Analysis - Blank) / 1000) / Vol * 260.33 ✓
A	Silica Gel	✓		ug		T6 = 1ppm		
B	ORBO-22	✓		~~ug~~				

~~6F/5m is only for Asbestos~~

COLUMN WRITE 8 1/2 x 11 PADDED / WG7612 - WRITING ROUND -

CTD026406

	Initials	Date
Prepared By		
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as of 9/15/89

✓	5	Asphalt Fume/Total [redacted]		Mg	mg/m3			(Analysis - Blank)/(VOL/1000) ✓
2		[redacted]/SM	✓	weight	E	analysis	30A&B 1/89	
3		[redacted]	✓	weight	F			
4		[redacted]-B(PVC)	✓	weight	G			
5		[redacted]		weight	H			
9/15/89		[redacted]		weight		See 121A-D AFBS		
7		[redacted]			ug	ppm	0-35ppm 17.0	((analysis - Blank)/1000)/VOL * 1441.18 ✓
8		[redacted] Gel					Ib = 10ppm	
9								
10								
11								
12								
13	7	Sodium		S	ug	mg/m3		(analysis - Blank)/(volume/1000)
14		A Impinger		SC	Sod Carb	(140A)		
15				SB	Sod Bonate	(141A)		
16				SS	Sod Sulfate	(142A)		
17								
18	8	PCB		PC	ug	mg/m3		((Analysis - Blank)/1000)/(VOL/1000)
19		A Florisil	✓					
20		B GF/SM						
21		C GF						
22								
23	9	Fluoride Dust		FD	ug	mg/m3	0=2.5mg/m3	((Analysis - Blank/1000)/(VOL/1000)
24		A Prefilter to impinger	✓					
25		B 37mm MW CEF	✓					
26								
27								
28								
29								
30								

NIOSH REC LIMIT = 5mg/m3

COMPANY U.S.A. - COLUMN WRITE G7612 PADDED / WG7612 WIPING BOUND

	Initials	Date
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✓	10	Hydrogen Fluoride HF	ug	ppm	0 = 3ppm	20.01	((Analysis - Blank)/1000)/VOL * 1224.39
	A	Impinger ✓ also					
	B	Filter ✓ Hydrofluoric Acid			← Method 7902 NIOSH FLUORIDES		
✓	11	~~Total Fluoride TF~~	~~ug~~	~~mg/m3~~	~~0 = 2.5mg/m3~~		~~((Analysis - Blank)/1000)/(Vol/1000)~~ now 09B 2/9/90 tmf/mek
	A	~~Filter - Sod Form ✓~~					
		~~[illegible]~~	~~Make 9B~~				
✓	12	Hydrogen Cyanide HC	ug	ppm	0 = 10ppm	27.03	((Analysis - Blank)/1000)/VOL * 906.40
	A	Impinger .1N KOH					
	B	Imp NaOH soln (1N) HCN	mg	ppm			"
✓	13	Hydrogen Sulfide HS	ug	ppm	0 = 20ppm	34.08	((Analysis - Blank)/1000)/VOL * 718.89
	A	Impinger ✓ water			~~Method PCAM 168 or PCAM 146 or PCAM 163 or 5308~~		PCAM 128
	14	Sulfur Dioxide SD		ppm	0 = 5ppm	64.07	
	A	Impinger Na ✓ NaOH?	ml				> (Analysis - Blank)/VOL
	B	Impinger H Peroxide	ug	PCAM 163			> ((Analysis - Blank)/1000)/VOL * 382.39
	C	special Whatman filter/MCE	ug	ppm			"
		~~A & C same~~					
	15	Chromium Dust CR	ug	mg/m3	0 = 1mg/m3		((Analysis - Blank)/1000)/(VOL/1000)
	A	~~MW Millipore~~ ✓ by AA					
	B	~~[illegible]~~ anal = Result			~~[illegible]~~		
	C	MW Millipore by ICP					
	D	~~[illegible]~~ SD DI Equal					

COLUMN WRITE U.S.A. - "COLUMN WRITE" G7612 PADDED / WG7612 "WYRING" BOUND

	Initials	Date
Prepared By		
Approved By		

							MW	
16	A	Methylene Chloride C. Tubes ✓	MC	mg	ppm	0-500ppm	84.94	(Analysis - Blank)/VOL * 288.44
17	A	Isopropyl Alcohol C Tubes ✓	IA	mg	ppm	0=400ppm	60.09	(Analysis - Blank)/VOL * 407.72
18	A	Sulfuric Acid ✓ ~~Imp - Hyd Perox~~	SA	ug	mg/m3		96	((Analysis - Blank)/1000)/(VOL/1000)
19		~~[illegible]~~ ABS ~~[illegible]~~ ✓ ~~[illegible]~~	AB	fibers/fields 100	f/cc			same as #2 A
		[redacted]		MAKE CHANGE				does not divide by 2 Note in Calc conv. factor
		[redacted]		mpp of				Results = analysis (Historical Data) Analysis = Results (Hillsboro 1966 Historical
~~20~~	~~A~~	~~Methyl Chloroform C Tube~~	~~MA~~	~~mg~~	~~ppm~~	~~0=350ppm~~	~~33.4~~	~~(Analysis - Blank)/VOL * 183.66~~ now 56A 2/9/90 tmf/mck
21	A	~~Ethyl~~ Cellosolve C Tube ✓ (2-ETHOXY ETHANOL) ← correct gal 11/90	EC	ug	ppm	A=5ppm	90.12	((Analysis - Blank)/1000)/VOL * 271.86
							OSHA METHOD 53 Equivalent	

COMPANY U.S.A. - COLUMN WRITE G7612 PADDED / WG7612 WYRING BOUND -

*Skin

	Initials	Date
Prepared By		
Approved By		

22		Methyl Cellosolve	ML	ug	ppm	A = 5ppm D = 25ppm*	76.09	((analysis - Blank)/1000)/VOL * 32199
	A	C Tube ✓						
23		Propanol ✓ (N, Propyl alcohol) same as 17	PR	ug	ppm	A = 200ppm	60.09	((analysis - Blank)/1000)/VOL * 407.72
	A	C Tube						
	B	C Tube	PALL	UG	PPM	D = same as		"
24		IRON OXIDE	IO	ug	mg/m3	10mg/m3		same as 25
	A	37mm CEF Fume						
	B	MW millipore (by ICP)						
25		N,N Dimethyl Aniline	MA	ug	mg/m3			((analysis - Blank)/1000)/(VOL/1000)
	A	NIOSH PCAM 168 ✓	Silica Gel					
26		Silica (Quartz, Crystalline)		same				
→	A	Total ✓	ST	mg	mg/m3			(Analysis - Blank)/(VOL/1000)
→	B	OK Respir ✓	SR	mg	mg/m3	using CT preweighed filters		as of 6/21/88 [illegible] TMF
		[redacted]				old method		
→	D	Respirable		mg	mg/m3	(using Natisco's PVC preweighed filters)		11/90 JR
→	E	Total		mg	mg/m3	(using Natisco's PVC preweighed filters)		11/90 JR
27		Sodium Hydroxide	SH	ug	mg/m3			((analysis - Blank)/1000)/(VOL/1000)
	A	Impinger						
[redacted]			AL	ug	mg/m3			same as 25
	A	NIOSH PCAM 168 ✓						
		Silica Gel 1		NIOSH Method 2002 Aromatic Amines Silica Gel				

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JONES COMPANY U.S.A. · COLUMN WRITE G7612 PADDED / WG7612 WYRING BOUND ·

CTD026410

	Initials	Date
Prepared By		
Approved By		

[redacted]		AR	ug	ug mg/m3	0=10mg/m3		(Analysis - Blank)/(Vol/1000)	
30	Benzene Soluble	BS	mg	mg/m3			(Analysis - Blank)/(Vol/1000)	
A								
B	Teflon	Moved to 5E-H						
31	Hexane (Tot Org)	HX	ug	ppm		86.2	((Analysis - Blank)/1000)/Vol * 284.22	move 62A 2/9/90 tmf/mek
A	CT							
32	Hydro Chloric	HY	ug					
A	MSA I Impinger mg/m3			mg/m3	0=1mg/m3	mg/m3	((Analysis - Blank)/1000)/(Vol/1000) = mg/m3	
B	" ppm			ppm	0=5ppm	36.47	((Analysis - Blank)/1000)/Vol * 671.79	
33	Hydrobromic	HB	ug	mg/m3			same as 32	
A	Impinger							
[redacted]	[redacted] Quartz	BA	ug	mg/m3	0=0.5mg/m3		same as 15	
A	[redacted]							
	CEF-37mm MW							Matched Wt MCEF

PCAm115 — Na Iodide w/H2O

WILSON JONES COMPANY U.S.A. · COLUMN WRITE G7612 PADDED / WG7612 WYRING BOUND

	Initials	Date
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35	A	Phosphoric Impinger	PH	ug	mg/m3				same as 32		
36	A	Nitric Acid Impinger	NA	ug	mg/m3				same as 32		
37	A	O-Toluidine Sil Gel NIOSH PCAM 168	OT	ug	mg/m3				same as 25		
38	A	Acrolein Acro Bisulfate Silica	AC	ug	ppm	93.1ppm	56.07	((Analysis-Blank)/1000)/Vol.*436.95			
39	A	2,4 Xylidine PCAM 169 SGel	XY	ug	mg/m3				same as 25		
40	A	O-Anisidine PCAM 168 Sil Gel	OA	ug	mg/m3				same as 25		

CTD026412

	Initials	Date
Prepared By		
Approved By		

| | | |

	Initials	Date
Prepared By		
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		1	2	3	4	5	6	7	8	9	10	11	12
						MW							
[redacted]		1,1,1 Trichloroethane (Tube)	TR	mg	ppm	O = 350 ppm	133.4	(Analysis - Blank) / Vol * 183.65					
57		Wood Dust (Hard)	WD			O = 5 mg/m³		and Resin					
	A												
58		Vinyl Chloride ✓	VC	mg	ppm	O = 1 ppm	62.5	(Analysis - Blank) / 1000 / Vol * 392.0					
	A	(B) (Historical Data - No		calculations)		STEL = 5 ppm		1. Badger (Direct) no calculations straight ppm					
[redacted]		[redacted]	AM	mg		A-5 mg/m³ See 193A		Atomic Absorption					
		[redacted]		mg	mg/m³	PEL = 15 mg/m³		(Analysis - Blank) / 1000 / (Vol Wood)					
60		Penta Chlorophenol ✓	PP	mg	mg/m³	Same as	3A						
	(M)	Glass fiber & Glycol	(Acetylene)										
61	A	Xylene ✓	XY	mg	ppm	O = 100 ppm		(Analysis - Blank) / 1000 / Vol * 284.30					
		[redacted]											
62	A	Petroleum Distillates -	PD	mg	ppm	O = 400 ppm		(Analysis - Blank) / Vol * 284.29 Cost as Hexane					
	D	Naptha (coal tar)						b) OSHA 2 Fluorides					
63		Silicon ✓	GL		mg/m³	A = 10 mg/m3							
	N	PVC Dust											
64		Xylene ✓	XY	mg			106.16	(Analysis - Blank) / 1000 / Vol * 230.78					
	A												
65		Toluene ✓	T	mg	ppm	O = 200 ppm	92.13	(Analysis - Blank) / 1000 / Vol * 265.92					
	A	C Tube											
66		Freon ✓			mg 2 4A								
	A												
67		Talc ✓	TC	mppcf	mppcf	O = 20 mppcf		no calculations use actual #					
	A												
[redacted]		[redacted]	CA	mg	mg/m³	O = 0.2 mg/m³		same as 15					
69		Trichloroethylene	TE	mg	ppm		165.85	(Analysis - Blank) / Vol * 147.72					
	A	C Tube											
70		Styrene ✓	SY	mg	ppm	O = 100 ppm	104.14	(Analysis - Blank) / Vol * 235.26					
	A					A = 50 ppm							

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CTD026414

$\frac{mg}{Vol} \times 1000 \times 24.5 \div MW = ppm$

$\frac{24,500}{MW}$

	Initials	Date
Prepared By		
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		[redacted] Dust	CX	mg	mg/m³	O = 0.01 mg/m³		Same as 15					
72	A	Methanol	MT	mg	ppm	O = 200 ppm A = 200 ppm *	32.04	(Analysis - Blank) / 1000 / Vol *	764.67				
73	A	Organic Tin (mixed)	OT	mg	mg/m³	O = 0.1 mg/m³	-	(Analysis - Blank) / 1000 / (Vol / 1000)					
	B	XAD-2 Tubes (Hg) (8/86) (HO3) (165)											
74	A	Titanium Dioxide	TT	mg	mg/m³	O = 15 mg/m³	-	(Analysis - Blank) 1000 / (Vol / 1000)					
		[redacted]	BZ	mg	ppm	O = 10 ppm	78.11	((Analysis - Blank) / 1000) / Vol *	313.7				
76	A	Methyl Ethyl Ketone	ME	mg	ppm	O = 200 ppm	72.1	((Analysis - Blank) / 1000) / Vol *	339.8				
	B	"			ppm = Result								
77	B	Tetrahydrofuran	TH	mg	ppm	O = 200 ppm	72.1	Same as 76A		Cannot take ?			
	B	"			ppm = Result								
78		Yeast	G	mg	mg/m³	A = 10 mg/m³	-	Same as 3A		Dupe is 63A			
	A												
		[redacted]	CB	mg	mg/m³	O = 3.5 mg/m³							
		Occidental Chemical				B = Mallcco Software Subtraction Method							
80		MDI	MD	mg	PPM	O = .02 ppm	250.27	(Analysis - Blank) 1000 / Vol *	97.89				
	A	80B - MD 7 Bx 37 mm PSG (Nitro-Impreg) OSHA Method 47											
81		Naptha TWICE	NP	mg	ppm	O = 100 ppm	100.0						
	A												
		Acrylonitrile	AY	mg	ppm	A = 2 ppm O = 2 ppm	53.07	((Analysis - Blank) / 1000) / Vol *	1461.65				
83		Antimony Oxide	[redacted]	mg	ppm	O = 50 ppm (S)	42.07	(Analysis - Blank) / 1000) / Vol *	3941.72				
	A	Ethylene Glycol = 37 mm PSG	EG										
		[redacted]	[redacted]	mg	mg/m³								
85		PNA: Phenanthrene	PT	mg	mg/m³								
	A & B	Glassfiber	[redacted]	mg	mg/m³	Teflon							
86		PNA's Pyrene	PY	mg	mg/m³								

CTD026415

	Initials	Date
Prepared By		
Approved By		

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								MW	cal
		[redacted]	CY	ug	ug/m3				
		[redacted]	BN	ug	ug/m3				
		[redacted]		ug	ppm	0-10ppm		73.11	.335 x 1000 = 335.1
	A	500mg Silica gel		=	Percent				
		[redacted]	CC	ug	ppm	0-50ppm		98.1	((analysis - blank)/1000) / Vol x 249.74
91		Epichlorohydrin	EP	ug	ppm	0-5ppm		92.5	((anal - blank) / 100000) / Vol x 264.86
	A								
92									
	A	ZINC fume (dust see 125A)	Z	mg/ug	mg/m3	ACGIH 5mg/m3			~~(Anal - Blank) / (Vol / 1000)~~ ((Analysis - Blank)/1000)/Vol/1000
93	A	Wood Dust (soft)	WS	mg	mg/m3	0-5 MG/M3			
94	A	~~Cyclohexanone~~							
94	A	Methyl Methacrylate	MT	ug	ppm	0-100ppm		100.13	(Analysis - Blank/1000)/Vol x 244.18
95	A	Dimethyl Formamide	DF	ppm	ppm	= Percent			
	B	[redacted]		ppm				73.11	(Analysis - Blank)(1000) / Vol x 335.1 (2/9/90 mg/mg)
		[redacted]	VG	ug	MG/m3				(same as 15)
	B	Try ICP							
		[redacted]	VG	ug	MG/m3	0-0.5 mg/m3			(same as 15)
		[redacted]		To D2	9-11A				
98	A	~~Sulfates~~ Mineral Spirits (MS) CTube		ug	mg/m3	~~0-350 mg/m3~~			((Analysis - Blank)/1000)/(Vol/1000)
									GASTEC 170/a-L
99		[redacted]	CM	mcl	ppm	0-35	1989		~~((Analysis - Blank)/1000)/Vol x 249.74~~ Long Term Detector Tube
		[redacted]			ppm				~~Analysis = Result~~ Long Term Detector Tube
		[redacted]		mcg	MG/m3	0-.5 mg/m3			((Anal - Blank)/1000)/(Vol/1000) *Dräger 5/a

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CTD026416

	Initials	Date
Prepared By		
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			1 abbrev	2 Computer units	3 Result units	4 PEL/TLV	5 Mol wt	6 Calc	7	8	9	10	11	12
101		Heptane	HP	ug	PPM	PEL=400	100.2							
	A	Charcoal Tube							(Canalysis - Blank)/1000)/1.01 * 24.49					
102		Trichloroethylene	TY	ug	PPM	PEL=50	131.38							
	A	Charcoal Tube							((Canalysis - Blank)/1000)/Vol * 186.78					
103		V/M & P Naptha (w/ Hexane)												
	A	Char. Tube	VM	ug	ppm	0-300	86.18 (mW-Hexane)		(Canalysis - Blank)/1000)/Vol * 284.3					
[redacted]			CL	ug	mg/m3	PEL=0.5	—							
105		Heptachlor	HE	ug	mg/m3	PEL=.5	—							
	A	Chromosorb 102												
106		Methylene Chloride	VD	ug	ppm	1-100ppm T-5	96.94		(Canalysis - Blank)/1000)/Vol * 352.73					
	A	- C Tube												
~~109~~		~~Benzene~~	AH											
	A	~~as the Indicator~~	AH	mg	mg/m3	15mg/m3= PEL	—		(Canalysis - Blank) ~~/ (Vol/1000)~~					
[redacted]		Tri-Substitute	ED	ug	ppm		54.09		(Canalysis - blank)/1000)/Vol X 452.94					
109	A	Total Hydrocarbons as Hexane	HAT	ug	ppm		86.2		Canalysis - Blank)/Vol(X1000) * 284.72 now 24.4 (1/1000 2/9/90 mg/METER)					
110		Di Oct yl Phthlate (DOP)	DO	ug	ug/m3	0-5mg/m3			(Canalysis - Blank/1000)/(Vol/1000)					
	A	Glass fiber												
	B	Teflon filter												
111		PVA Polyvinyl Alcohol	PV	mg	mg/m3	[redacted]	[redacted]		(Canalysis - Blank)/(Vol/1000)					
	A													
112	A	~~Hydrated Aluminum~~ 126 & Chgd to alum Brickerd	HR	ug	ug/m3 1/1000	1	-		Canalysis - Blank)/(Vol/1000					

11/28/90

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CTD026417

	Initials	Date
Prepared By		
Approved By		

			1	2	3	4	5	6	7	8	9	10	11	12
							NIOSH 1300		M.W.	Calc				
1	113		Methyl Isobutyl ketone	MIK (Hexone)	0-500ppm	7555	CAM: 50ppm		100.18	((Analysis - Blank)/1000))/VOL				#244.56
2		A		(4Methyl 2pentanone)										2
3	114		Ethanol	E (IPA)	0-1000ppm		con 1000ppm		46.08					#531.68
4		A												4
5	[redacted]			BU (1,2 Butoxyethanol)	0-25ppm		con 25ppm		118.20					#207.28
6														6
7	116		Oil Mist (mineral)	OM	mg	mg/m3 0.5mg/m3	con 5mg/m3			((Analysis - Blank)/1000)/Vol/1000)				7
8		A	Glass Fiber Soluble	Total Dust	Gravimetric									8
9		B	PVC (Dual filter) non	Soluble	Fluorescence									9
10														10
11	117		Lip appliance Group	DP	mg	1ppm PEL=100			148	((Analysis) - Blank/1000) Vol * 165.54				11
12			Methyl Ether			STEL=150								12
13		A	CG	CHARCOAL TUBE										13
14	118		Silica Quartz (Cristobalite)	CT			(Analysis	Blank)		)/(Vol/1,000)				14
15		A	PVC Total (B) PVC											15
16	119		Silica Quartz (Tridymite)	TM			same →							16
17		A	PVC Total (B) PVC											17
18	120	A	Resp Dust	RD	mg	mg/m3 Using CT PVC filters same								18
19		B	PVC Filter			Using Matched PVC filters previously								19
20	[redacted]		[redacted] Benz/BS	[redacted]	mg					→ same				20
21			[redacted]											21
22	15/8		[redacted]											22
23			[redacted]											23
24														24
25	~~112~~	A	~~Cyclohexanone~~	~~CC~~										25
26			~~CT~~											26
27	121	A	VIN [redacted]	VM	mcg	mg/m3 12/79								27
28			[redacted]											28
29			[redacted]	COB	mcg	PEL=.05mg/m3	(Analysis - Blank)/1000/(Vol/1000)							29
30		B	by ICP 10A/89											30

B = by ICP [illegible] Lead forms see 92

9 1/4 EP

Benzene = (Analysis - Blank)(1000/Vol)

(Analysis - Blank/Vol)/1000

CTD026418

	Initials	Date
Prepared By		
Approved By		

calculation:

[redacted] ANF (same as 97A - antimony dust)

127	A	Tin (~~dust~~) inorganic cmpds	TN	mcg			((anal-blk)/1000)/(vol/1000)
128		Aluminum Oxide	ALO	mcg	mg/m³	TLV=10 mg/m³	((analysis-blank)/1000)/(vol/1000)
	A	10/9/89 - MWCEF					matched at MCEF
129		Tin Oxide	TNO	mcg	mg/m³	OSHA PEL = 2 mg/m³	(analysis - blank)/1000 / (vol/1000)
	A	MW CEF					matched wt MCEF
130		Kerosene	K				
	A	CT		mcg	mg/m³	OSHA PEL (Naptha) = 1600 mg/m³	((analysis - blank)/1000)/(vol/1000)
						↳ AKA Petroleum Distillates	
~~131~~	~~A~~	~~Total Solvent (as Hexane) CT~~	~~TSH~~	~~mcg~~	~~ppm~~	~~OSHA PEL = NOT APPLICABLE MOL WT = 86.18~~	~~(analysis - blank)/1000 / vol * 284.3~~ now 62A 2/9/90
132		Carbon Fiber	CF	mg	mg/m³		Same as 3A
	A	Thal Wt					
133		Welding Fume	WF	mg			Same as 3A or 3C
	A	PVC					
	C	MCE MATCHED WT					
134	A	ETHYL ACETATE CT	VCM Bond	EA			
							rults = analysis
135		Beryllium	BE	1 mcg	mg/m³	OSHA PEL = 0.002 mg/m³	((anal-blk)/1000)/(vol/1000)
	A	ICP method	NT300				

CTD026419

	Initials	Date
Prepared By		
Approved By		

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			1	2	3	4	5	6	7	8	9	10	11	12
							MW=							
136	A	VANADIUM by ICP	VN	mcg	mg/m^3	OSHA PEL = 0.05 for V_2O_5		((anal - blk)/1000) / ((vol/1000)						
137	A	MOLYBDENUM Total, by ICP	MO	mcg	mg/m^3	OSHA PEL 5mg/m³ Resp; 10mg/m³ Total							((anal - blk)/1000) / ((vol/1000)	
138	A	VINYL ACETATE	VA	mcg	ppm	ACGIH TLV 10ppm OSHA METHOD 51 Equivalent	MW = 86.09		((anal - blank)/1000) / VOL × 284.59					
139	A	Acetic Acid	AA	mcg	ppm	ACGIH TLV = 10 ppm OSHA METHOD 1B Equivalent	MW = 60.06		((anal - blank/1000 / Vol × 407.93					
140	A	Sodium Carbonate	See 7A											
141	A	Sodium Borate	See 7A											
142	A	Sodium Sulfate	See 7A											
143	A	Aluminum Fume	AMF	0-5mg/m³	µg	mg/m³	same as 15							
144	A	Cadmium Fume +B	CAF	µg	mg/m³									
145A		Chromium Fume +B & C	CRF	µg	mg/m³									

DON JONES COMPANY, U.S.A. • COLUMN WRITE 07612 PADDED / WG7612 WIRING BOUND

CTD026420

	Initials	Date
Prepared By		
Approved By		

COLUMN WRITE®

| | | |

	Initials	Date
Prepared By		
Approved By		

									Chem Master #	MW					
162	A	~~[illegible]~~ FREON 11	~~[illegible]~~ F11	ug	PPM	OSHA 1000 PPM CEILING	1128	137.36	((analysis - Blk)/1000)/Vol *	178.36					
163	A	Butylamine VAPOR	BTA	MG	PPM		360	73.16	(analysis - Blk) [redacted] /Vol ~~[illegible]~~	328.05					
164	A	Acrylamide VAPOR	ACM	UG	PPM		35	71.09	(analysis - Blk)/1000/Vol *	344.63					
165	A	NO_x VAPOR	NOX	UG	PPM		1624 NO_2 =	46.01	((analy - Blk)/1000)/Vol *	532.49					

WILSON JONES COMPANY U.S.A. · COLUMN WRITE G7612 PADDED / WG7612 WIRING BOUND ·

BY Contam 1st yr used plant

Aluminum Dust 59A

Samples for aluminum dust were obtained following the NIOSH Method P&CAM 173 as taken from the NIOSH Manual of Analytical Methods.

Personal samples were obtained using a cellulose ester filter with a DuPont P4000 pump calibrated to approximately 1.5 liters per minute. Samples were sent to NATLSCO, Long Grove, Illinois for analysis by atomic absorption.

The OSHA limit for aluminum dust is 15 mg/m3, the total inert and nuisance dust limit.

Ammonia 6A

~~Detector tube~~ area samples were obtained using the Bendix ~~detector~~ tube pump and Bendix detector tubes for ammonia.

Personal samples were taken using acid washed silica gel tubes and DuPont P200A sampling pumps which were calibrated to 150 cubic centimeters per minute (cc/min.). The OSHA standard (29CFR1910.1000, Table Z-1) limits exposure to 50 ppm for an 8-hour time-weighted average.

Prefilter

Asbestos 19B~~&C~~

The sampling and analysis was conducted following the current OSHA Standard 29CFR1910.1001, Appendix A ORM (Mandatory).

Personal samples were obtained open faced on a 25mm 0.8 micron mixed cellulose ester Millipore filter with a 50mm extension cowl. DuPont Alpha I, P4000 and P2500 air sampling pumps were calibrated before and after each sampling day to approximately 1 liter per minute. In most cases, a series of two, three or four different filter samples were obtained for the person, to establish an 8-hour time-weighted average (TWA) concentration.

The analysis was conducted by NATLSCO Labs, Long Grove, Illinois. The counts were made following the A counting rules as described in the Standard, Appendix A.

The current Standard calls for a personal exposure limit of 0.2 fibers, longer than 5 microns per cubic centimeter of air (f/cc) and an action limit of 0.1 f/cc.

Asphalt Fumes 5A 30A

Air sampling for total dust asphalt fumes was conducted with glass fiber & silver membrane filter cassettes. DuPont ALPHA

I and P4000 air sampling pumps were calibrated to sample air at a rate of approximately 2.0 liters per minute. The total dust asphalt fume content was analyzed by gravimetric method on a Cahn C-25 electrobalance. The benzene soluble method (NIOSH P&CAM 217) was used for analysis of asphalt fumes collected in a dusty atmosphere.

The calibration sampling and gravimetric analytical procedures followed those given in the OSHA Industrial Hygiene Field Operator Manual, Chapter 11, dated April 2, 1979, and the method given in the NIOSH Criteria for a Recommended Standard...Occupational Exposure to Asphalt Fumes, DHEW (NIOSH) Publication #78-106, September, 1977. In this criteria document, NIOSH recommends a ceiling limit of 5 mg/m3.

Chlordane

Samples were collected following the NIOSH Method P&CAM S278 (6/8/79). DuPont P4000 and Alpha I air sampling pumps were calibrated to approximately 1 liter per minute. A mixed cellulose ester membrane filter was used as a prefilter to trap chlordane particulate and was followed by a Chromosorb 102 sorbent tube. Samples were analyzed by NATLSCO Laboratories, Long Grove, Illinois, using gas chromatography. The current OSHA exposure limit is 0.5 mg/m3.

Chromium Dust 15A

Chromium dust samples were obtained on Millipore 0.8 micrometer cellulose ester filters using DuPont P4000 and P2500 air sampling pumps which were calibrated to a 1.7 liter per minute flow rate. Samples were analyzed by atomic absorption spectrometry by NATLSCO Laboratories, Long Grove, Illinois. The OSHA Standard, found in 29CFR1910.1000 is for chromium metal and insoluble salts.

Total & Respirable Dust Sampling 3A & 3B

Total dust and respirable dust samples were obtained on MSA FWS-B 5 micron polyvinyl chloride filters. Gravimetric analyses were accomplished on a Cahn C-25 electrobalance according to methods given in the OSHA Industrial Hygiene Field Operations Manual, April 2, 1979.

DuPont ALPHA I, P4000 and P2500 air sampling pumps were utilized for area and personal samples, and were calibrated at approximently 1.7 liters per minute before and after each sampling day. All respirable dust samples werre obtained through the use of 10 millimeter nylon cyclones, (MSA Respirable Dust Lapel Samplers).

26 A & B The percent free silica (quartz, christobalite, tridymite) in

the airborne dust samples were analyzed by the National Loss Control Service Corporation (NATLSCO of Long Grove, Illinois). The method utilized for this analysis was NIOSH Manual of Analytical Method, 2nd. Edition, P&CAM 259. This method utilized the redeposition of the particulate material into a silver membrane filter followed by x-ray diffraction scan for the silica peaks.

The limit for respirable inert or nuisance dust is 5 mg/m3 and total inert or nuisance dust is 15 mg/m3 per the current OSHA standard, 29CFR1910.1000, Table Z3. The OSHA permissible exposure for silica dust is a function of the percentage of silica in the dust sample obtained as follows:

Silica (Crystalline):

$$\text{Quartz (Respirable)} = \frac{10 \text{ mg/m3}}{\% \text{ SiO2} + 2}$$

$$\text{Quartz (Total Dust)} = \frac{30 \text{ mg/m3}}{\% \text{ SiO2} + 2}$$

Fiberglass 2B

Personal and Environmental samples were collected open face on a 25 mm, 0.8 micron mixed cellulose ester filter with DuPont ALPHA I, P4000 and P2500 pumps at a calibrated flow rate of approximately 1.5 lpm. Phase contrast microscopy was used at 400X to analyze for fiber content according to the method prescribed in the NIOSH Analytical Method Manual, 3rd Edition, 5/15/85 - Method #7400.

"Total Dust" fiberglass samples were obtained on MSA FWS-B polyvinylchloride filters. All dust weights were accomplished on a Cahn C-25 electrobalance. All filter weights were made in accordance with the instruction manual for the electrobalance, Model Cahn C-25 and according to the OSHA Industrial Hygiene Field Operations Manual dated April 2, 1979. DuPont P4000 air sampling pumps were utilized for area and personal samples were calibrated at 1.7 or 2.0 liters per minute. Calibration of the pumps was done before and after each sampling day.

OSHA has no specific standard which regulates fibrous glass. It has in the past been classified as an inert, nuisance dust with an applicable Permissible Exposure Level (PEL) of 15 mg/m3 (OSHA Safety and health Standards, 29CFR1910.1000, Table Z-3).

As of June 4, 1979, OSHA issued new instructions in their Industrial Hygiene Field Operations Manual (IHFOM) setting forth their administrative policy for the handling of health inspections and citations. The IHFOM instructs OSHA personnel to consider a general duty clause (Section 5 (A) (1) OSHAct) citation for an exposure in excess of an ACGIH Threshold Limit Value (TLV) or a NIOSH recommended value when there is no specific OSHA permissible exposure limit (PEL).

The 1978 Conference of Governmental Industrial Hygienists (ACGIH) recommends a TLV of 10 mg/m3 for fibrous glass with diameters less than 7 micrometers and for glass dust.

In April, 1979, the National Institute for Occupational Safety and Health (NIOSH) published "Criteria for a Recommended Standard...Occupational Exposure to Fibrous Glass", DHEW #77-152. In it they recommend that occupational exposure to fibrous glass be controlled so that no worker is exposed at an airborne concentration greater than 3,000,000 fibers per cubic meter of air (three fibers per cubic centimeter of air) having a diameter equal to or less than 3.5 micrometers (um) and a length equal to or greater than 10 micrometers determined as time-weighted average (TWA) concentration for up to an 10-hour work shift in a 40-hour week, and that airborne concentrations determined at total fibrous glass shall be limited to a TWA concentration of 5 milligrams per cubic meter of air.

It is not known at this time which standard would be held as the most appropriate by OSHA personnel.

Formaldehyde

Sodium Bisulfite - 1A

Air monitoring was conducted with DuPont ALPHA I and P4000 portable air sampling pumps calibrated to approximately 200 cc/min. Two midget impingers in series with 15 cc of sodium bisulfite solution was the absorber. Analysis was conducted by Walter Gubar at the Insulation Group's Blue Bell Laboratory utilizing the spectrophotometric method, NIOSH P&CAM 125.

Protek Badge - 1C

Air monitoring was conducted using DuPont formaldehyde monitoring badges. Analysis was conducted by Walter Gubar following the DuPont method utilizing a spectrometer.

Supelco Tube - 1B

Air monitoring was conducted with DuPont ALPHA I P4000 & P200 air sampling pumps calibrated to approximately 50 cc/min. Adsorption
was accomplished by using a glass tube containing a styrene-

divinylbenzene copolymer coated with N-benzylethanolamine supplied by Supelco (ORBO-22). Analysis was conducted by Bio Medical Laboratories, Salt Lake City, Utah, utilizing the proposed NIOSH method P&CAM 354 (E) - desorption with 150 - octane, capillary gas chromatography FID coated with N-benzylethanolamine.

The current OSHA limit given in 29CFR1910.1000, Table Z-2, is 3 ppm as a time-weighted average and an acceptable ceiling concentration of 5 ppm. The CertainTeed permissible exposure limit has been established at 0.5 ppm.

Formaldehyde and Phenol

Supelco Tube - 1B & 4B

Air monitoring was conducted with DuPont ALPHA I P4000 & P200 air sampling pumps calibrated to approximately 50 cc/min. Adsorption was accomplished by using a glass tube containing a styrene-divinylbenzene copolymer coated with N-benzylethanolamine supplied by Supelco (ORBO-22). Analysis was conducted by Bio Medical Laboratories, Salt Lake City, Utah, utilizing the proposed NIOSH method P&CAM 354 (E) - desorption with 150 -octane, capillary gas chromatography FID coated with N-benzylethanolamine.

The current OSHA limit for formaldehyde, given in 29CFR1910.1000, Table Z-2, is 3 ppm as a time-weighted average and an acceptable ceiling concentration of 5 ppm. The CertainTeed permissible exposure limit has been established at 0.5 ppm.

The current OSHA and CertainTeed permissible exposure limit for phenol is 5 ppm.

Glycerin 63A 78A ?

Personal and area samples for glycerin were obtained on MSA FWS-B polyvinyl chloride filters. Gravimetric Analyses were performed on a Cahn C-25 electrobalance. DuPont P4000 and P2500 air sampling pumps were calibrated at 2.0 lpm before and after each sampling day.

The threshold limit value (TLV) for glycerin mist as set by the American conference of Governmental Industrial Hygienists (ACGIH) is 10 mg/m3.

Hearing Conservation

Audiometric examinations are being conducted in the dispensary by the plant nurse. Baseline audiograms were reportedly completed. We recommend that the baseline audiograms and future annual audiograms be evaluated by a professional consultant such as

Impact Hearing Conservation, Inc.

We were informed that the employees were provided training in hearing conservation. This program should be reinforced, particularly as it applies to wearing of hearing protection where required. We strongly recommend that the mandatory wearing of hearing protection be enforced in those areas where exposures in excess of 100% were measured.

Wearing of hearing protection be managers, supervisors and visitors would also be enforced to protect their hearing and to serve as a motivational tool in enlisting the cooperation of all employees.

To assist you with your training programs, we have a copy of the National Safety Councils audio-slide program "Sound Sense" which we can provide on loan for your use. This program will meet the training requirements of the OSHA standard.

Heptachlor

Samples were collected following the NIOSH Method P&CAM S287, (1/19/78). DuPont P4000 and Alpha I air sampling pumps were calibrated to approximately 1 liter per minute. A Chromosorb 102 tube was used as the collection device. Samples were analyzed by NATLSCO Laboratories, Long Grove, Illinois, using gas chromatography. The current OSHA exposure limit in 0.5 mg/m3 with a skin notation.

Industrial Hygiene Survey
----------(Plant)
----------(Date)

An Industrial Hygiene Survey was conducted at the ---------- Plant by ---------- of Corporate Health and Safety on ----------.

This survey was conducted to supplement the ongoing in-plant ----- ---------- exposure surveillance program. Additional monitoring for ---------- and ---------- was performed.

This report is an employee exposure record as defined in Corporate Procedure GE003.02 and OSHA Standard 29CFR1910.20 and must be retained for thirty years. Upon request, this record must be made available to those Federal officials, employee designees or employees as provided for in Corporate Procedure AD0111, Paragraphs 7 and 8.

Appendix ---- of this report documents the air sampling methodologies, the analysis techniques and the current standards

need in evaluating the data. The field and in-house laboratory notes on this survey are on file in Corporate Health and Safety.

Miscellaneous

It is our standard procedure in taking personal exposure samples, to inform each employee of the purpose of the sample and what they should and should not do to invalidate the results.

Specific do's and don'ts are: To go about their work as normal, not to remove the sampler, disconnect the tubing or filter holder, or purposely contaminate the sampling tube or filter, not to shout into a dosimeter microphone or otherwise violate the sample by artificially exposing it to loud noises.

We request they inform us of any loss of integrity of the sample such as sampling tube or cassette accidentally coming off, dropping or otherwise subjecting the devices to unnecessary impacts. We strongly encourage plant management to similarly inform the employees when conducting their sampling programs.

We request that each employee be informed of exposure results in this survey as outlined in the corporate procedure. Employees whose asbestos and noise exposures exceed the PEL and the action level respectively, must be informed accordingly to OSHA regulation.

We suggest that a copy of the attached tables be posted on the employees bulletin board. Also, a Fiber Notification Form (FEN) must be completed as outlined in the Health Maintenance Manual, Asbestos Unit Program Section VII, for each employee sampled for asbestos. Alternately, the employees, including those in similar positions to those measured, can be informed personally.

We recommend that each employee be informed of the exposure results in this survey. Employees whose noise exposure measured in excess of 85 dBA must be informed by OSHA regulation. We suggest that a copy of Tables through be posted on the employees' bulletin board for that purpose. Alternately, the employees, including those in similar positions to those measured can be informed personally. Such notification should include measurements for both air contaminants and noise.

→ MEK 76A → THF 77A Cyclohexanone 90A

Noise

A Bruel & Kjaer (B & K) 2209 precision sound level meter with a B & K 1613 octave band analyzer and B & K 4133 1/2-inch microphone, or a B & K 2230 precision sound level meter with

B & K 1624 octave filter set and a B & K 4165 1/2-inch microphone, were/was utilized to obtain sound pressure level measurements. A B & K 4152 artificial ear with a B & K 4144 1-inch condenser microphone was used to calibrate the plant's audiometer. Calibrations were made with B & K 4230 calibrator before and after this survey. When obtaining sound level measurements in the plant, a 3-inch foam sphere was used as a microphone windscreen. The reference for all sound pressure level measurements is 0.0002 microbar.

DuPont Model D-376 and D-391 audiodosimeters utilized during this survey were set at the 80 dBA cutoff mode. The dosimeters were calibrated before and after each day of sampling utilizing the DuPont audiodosimeter calibrator Model C-114 by the direct reading method. Before and after each survey week the audiodosimeters were calibrated by the time calibration procedure utilizing the DuPont calibrator C-114 and Model R225 readout. this calibration was done for 5 minutes, 10 seconds at 114 dB to give an expected 30% +/- 4% result.

The Metrosonics db-301 & 308/653 Metrologging System was utilized during this survey. The db-301 & 308 dosimeters are used for collecting the basic sound level data in both a time history and statistical distribution computer program. The db-653 receives the data from the db-301 & 308, processes it, and provides a printout in two program formats. The 80 dB cutoff mode is incorporated into those programs.

The db-301 & 308 audiodosimeters and db-306 soundlevel analyzer were calibrated before and after each survey day with a Metrosonics CI-304 calibrator.

The permissible OSHA noise exposure, (29CFR1910.95), ranges between 90 decibels for 8 hours per day through 115 decibels for a maximum duration of 1/4-hour per day. The maximum permissible audiodosimeter dose is 100% on the 85 and 80 dBA modes.

Organic Tin

Polychlorinated Biphenyls 8A

PCB monitoring was conducted with DuPont P4000 and P200 air sampling pumps at a calibrated flow rate of 150 cc/min. through SKC florisil tubes. NATLSCO Laboratories, Long Grove, Illinois, analyzed the tubes for PCB based on Arochlor 1242 utilizing gas chromatography with electron capture detection. The method used was NIOSH P&CAM 244.

"PCB in fumes" monitoring was conducted with DuPont P4000 and P2500 air sampling pumps at a calibrated flow rate 1.7 lpm through glass fiber filters. Analysis was the same as for PCB above.
Pentachlorophenol, Naptha, and Petroleum Distillates

Samples for pentachlorophenol and naptha were obtained

following NATLSCO's variation of the NIOSH Method (S297) as taken from the NIOSH Manual of Analytical Methods.

Pentachlorophenol and Naptha 60A 61A

Personal and area samples were obtained using a glass fiber filter connected in series to a midget impinger containing 10 ml ethylene glycol. DuPont P4000 pumps were calibrated to approximately 1.0 liters per minute. Samples were sent to NATLSCO Laboratories, Long Grove, Illinois for analysis by high performance liquid chromatography.

The OSHA limit for pentachlorophenol is 0.5 mg/m3 with a skin notation as stated in the OSHA Standard CFR1910.1000.

The OSHA limit for naptha is 100 ppm as stated in the OSHA Standard CFR1910.1000.

Phenol 4A

Phenol samples were obtained with DuPont ALPHA I, P4000 and P200 pumps on silica gel tubes at a calibrated sampling rate of 200 cc/min. NATLSCO Laboratories, Long Grove, Illinois (AIHA Accredited) analyzed phenol by their field validated gas chromatography method. The current OSHA standard given in 29CFR1910.1000, Table Z-1 is 5 ppm.

Organic Tin 73A

Samples were collected on Millipore 0.8 micrometer cellulose ester matched weight filters with DuPont Alpha I and P4000 sampling pumps, calibrated to approximately 2.0 liters per minute. Analysis was performed by NATLSCO, Long Grove, IL. using atomic absorption spectrophotometry.

The OSHA permissible exposure limit for organic tin is 0.1 mg/m3.

Talc 67A

Talc is regulated under OSHA 29CFR1910.1000, Table Z-3, by the limit of 20 million particles per cubic foot (mppcf). The principal analytical method associated with this determination is generally viewed as archaic. It involves collecting the sample in a midget impinger and counting the particles in a Dunn cell with a light microscope. The alternative method utilizing sample collection on a Millipore filter with subsequent counting under a phase contrast light microscope was accomplished for samples reported as dust count, mppcf. In recent years, the development of gravimetric methods utilizing membrane filters and microbalances has in many instances replaced the impinger method for assessing dust exposures. The 1980 American Conference of Governmental Industrial Hygienists (ACGIH) TLV Booklet includes an appendix G, which deals with conversion of mppcf to mass

concentration. The conversion of three substances with OSHA limits of 20 mppcf (amorphous silica, mica, and soapstone) indicate equivalent threshold limit values of 3 mg/m3 respirable dust, and 6 mg/m3 total dust.

Titanium Dioxide 74A

Samples were collected on Millipore 0.8 micrometer cellulose ester, matched weight filters with a DuPont P4000 sampling pump calibrated to approximately 2.0 liters per minute. Analysis was performed by NATLSCO, Long Grove, IL, using atomic absorption spectrophotometry.

The OSHA permissible exposure limit for titanium dioxide is 15 mg/m3.

Vinyl Chloride Monomer 58A

The vinyl chloride samples were obtained and analyzed following the NIOSH P&CAM 178 method, as taken from the NIOSH Manual of Analytical Methods (April, 1977).

Personal and area samples were obtained on 500 mg charcoal tubes. DuPont ALPHA I, P4000 and P200 air sampling pumps were calibrated to 30 cc/min. before and after each sampling day.

DuPont "Protek" organic vapor air monitoring badge (Lot GAA101) were also utilized with one employee wearing both the "Protek" badge and the pump with charcoal tubes. This was done to generate data for method comparison for possible future use of the badge. These data are at this time inconclusive and are not reported within this report.

The vinyl chloride samples obtained on charcoal tubes and on "Protek" badges were sent to NATLSCO Laboratories, Chicago, Illinois, for analysis by gas chromatography.

The OSHA limit for vinyl chloride as stated in OSHA Safety and health Standards 1910.1017 is 1 ppm (part per million) averaged over an 8-hour period. For short exposures, less than 15 minutes, the permissible exposure is 5 ppm. The VCM action level is 0.5 ppm.

Welding Fumes (Nickel 55A, Chromium 15A, Manganese 54A, Iron 24A – 66A ?)

arsenic 39A
Cadmium 68A

Personal samples were collected on Millipore 0.8 micrometer cellulose ester filters with a Dupont P2500 sampling pump. The pump was calibrated at a flow rate of 1.5 liters per minute before and after each sampling period.

Analysis is performed by NATLSCO following the NIOSH Manual of analytical Methods, 2nd Edition, Validated Methods, S206

Zinc 92A

(Nickel);
S352 (Chromium); and S5 (Manganese). The analytical procedure involves acid digestion of the filter matrix and analysis by atomic absorption spectroscopy.

These metals are limited to the following airborne concentrations.

- Nickel, 1 mg/m3, TWA
- Chromium, 1 mg/m3, TWA
- Manganese, 5 mg/m3, Ceiling
- Iron, 10 mg/m3, TWA

Wood Dust 57A & 93A

Wood dust samples were obtained on MSA FWS-8 polyvinyl chloride filters, closed face. Gravimetric analyses were accomplished on a Cahn C-25 electrobalance according to methods given in the OSHA Industrial Hygiene Field operations Manual, April 2, 1979. DuPont ALPHA 1, P4000 and P2500 air sampling pumps were utilized for area and personal samples, and were calibrated to approximately 1.7 -2.0 liters per minute before and after each sampling day.

Presently OSHA has no exposure limit for wood dust and applies the inert of nuisance total dust limit of 15 mg/m3. The American Conference of Governmental Industrial Hygienist (ACGIH) has established threshold limit values (TVL) of 1.0 mg/m3 for hardwoods and 5.0 mg/m3 for softwoods.

Xylene and Toluene 64A 66A

Samples for xylene and toluene were obtained and analyzed following NIOSH Methods (S318 - xylene and S343 - toluene) as taken from the NIOSH Manual of Analytical Methods.

Personal samples were obtained on 500 mg charcoal tubes with DuPont P200 air sampling pumps calibrated to approximately 100 c/min. before and after each sampling day. The samples were then sent to NATLSCO Laboratories, Long Grove, Illinois, for analysis be gas chromatography.

The OSHA limit for xylene is 100 ppm (parts per million) and toluene is 200 ppm as stated in the OSHA Standard CFR1910.1000.