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HASKELL LABORATORY
FOR
TOXICOLOGY AND INDUSTRIAL MEDICINE

August 24, 1981

Mr. Ronald E. Benton
Assistant Manager
Environmental & Industrial Hygiene
Reynolds Aluminum
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P.O. Box 27003
Richmond, VA 23261

Dear Mr. Benton:

Attached is a copy of Talk #251 entitled "Procedures for Determining Working Protection Factors" which was presented at the American Industrial Hygiene Conference by Amy C. Simon on May 28, 1981. Numbers in the parentheses in the text refer to slides which are attached at the end. Please note that this is in draft form and we intend to publish the paper shortly. This may not be cited or reproduced in any form without permission.

Sincerely,

Amy C. Simon

Amy C. Simon
Industrial Hygienist

ACS/dar
Attachment

DRAFT

PROCEDURES FOR DETERMINING WORKING PROTECTION FACTORS

Paper #251 presented at AIHA by Amy C. Simon - Du Pont

RESPIRATORS ARE USED IN OCCUPATIONAL SITUATIONS WHEN ENGINEERING CONTROLS HAVE NOT SUFFICIENTLY REDUCED CONTAMINANT LEVELS TO THEIR EXPOSURE LIMITS. FIT TESTING IS CONDUCTED TO ASSURE THAT A PROPERLY FITTING RESPIRATOR HAS BEEN ASSIGNED. DURING THE FIT TEST, THE SUBJECT PERFORMS A SERIES OF TEST EXERCISES TO SIMULATE MOVEMENTS HE WOULD MAKE IN THE WORKPLACE. HOWEVER, THE ACTUAL PROTECTION GIVEN BY THE RESPIRATOR IN A WORKING SITUATION MAY BE DIFFERENT FROM THAT SEEN IN THE FIT TEST.

THE PROTECTION OFFERED IN THE WORKPLACE IS DETERMINED BY SEVERAL FACTORS. THESE INCLUDE HOW WELL THE RESPIRATOR INITIALLY FITS THE INDIVIDUAL, WEARING PRACTICES OF THE USER, THE EFFICIENCY OF THE FILTRATION MEDIA, SUCH AS ACTIVATED CHARCOAL OR PARTICULATE FILTERS, AND THE MAINTENANCE OF THE RESPIRATOR. TO EVALUATE THIS PROTECTION, IT IS NECESSARY TO EXAMINE THE EFFICIENCY AND USE OF THE RESPIRATOR IN THE WORKPLACE.

THE WORKING PROTECTION FACTOR IS THE PROTECTION PROVIDED BY THE RESPIRATOR IN THE WORKPLACE WHILE THE RESPIRATOR IS BEING WORN. IT IS MEASURED BY SAMPLING OUTSIDE AND INSIDE OF THE RESPIRATOR. (1)THUS, IT IS THE RATIO OF

THE TIME-WEIGHTED AVERAGE OF THE AIR CONCENTRATION OUTSIDE OF THE RESPIRATOR TO THE TIME-WEIGHTED AVERAGE CONCENTRATION OF CONTAMINANT INSIDE THE RESPIRATOR.

IN EVALUATING WORKING PROTECTION FACTORS WE ARE LOOKING AT THE TIME-WEIGHTED AVERAGE CONCENTRATIONS WHILE THE RESPIRATOR IS WORN. WE WILL NOT INCLUDE ANY TIME PERIODS WHEN THE RESPIRATOR IS OFF THE FACE. THEREFORE, WE ARE STUDYING RESPIRATOR PERFORMANCE AND NOT A PERSON'S EXPOSURE OVER THE TOTAL SHIFT.

TODAY I WILL DISCUSS A DESIGN FOR WORKING PROTECTION FACTOR STUDIES, AN EXAMPLE OF HOW THIS DESIGN WORKS, AND SOME PRELIMINARY RESULTS THAT WE HAVE OBTAINED. WE HAVE FOUND THAT A WORKING PROTECTION FACTOR STUDY INVOLVES MORE THAN MERELY TAKING SAMPLES. CONSIDERABLE PRELIMINARY WORK MUST BE DONE TO ENSURE THAT THE RESULTS WILL BE RELIABLE AND CONSISTENT.

OUR DESIGN INCLUDES TWO PHASES:

- PRELIMINARY ASSESSMENTS.
- COLLECTION OF DATA.

PRELIMINARY ASSESSMENT EVALUATES THE SUITABILITY OF THE WORKPLACE FOR CONDUCTING A WORKING PROTECTION FACTOR STUDY. THINGS TO CONSIDER INCLUDE:

- KNOWLEDGE OF THE WORKPLACE.
- RESPIRATOR PROGRAM.
- ANALYTICAL CAPABILITIES.

LET'S LOOK AT EACH OF THESE SEPARATELY AND THEN I WILL DISCUSS HOW THEY ARE ALL INTERRELATED.

KNOWLEDGE OF THE WORKPLACE SHOULD INCLUDE:

- ARE RESPIRATORS BEING USED IN THE WORKPLACE?
- HOW LONG ARE THEY WORN?
- WHAT CONTAMINANTS ARE PRESENT?
  AT WHAT LEVELS ARE THEY PRESENT?
- ARE THESE LEVELS PREDICTIBLE?

THE SECOND CONSIDERATION IS THE QUALITY OF THE RESPIRATOR PROGRAM. IT IS SENSELESS TO COLLECT DATA ON A RESPIRATOR PROGRAM OF POOR QUALITY. KEY ITEMS USED IN EVALUATING THE RESPIRATOR PROGRAM ARE:

- WHAT TYPE OF RRESPIRATOR IS BEING USED?

- Is it appropriate for the contaminant and level of contaminant.

- Are the people trained in the use of the equipment and have they been fit tested?

- Is the equipment maintained properly.

Finally the analytical capabilities must be considered. In evaluating working protection factors two quantities are measured: the concentration inside the respirator and the concentration outside of the respirator. Our ability to measure these is highly dependent on our analytical capabilities.

First, the measurement of the outside sample. As with any workplace sample the amount collected must be greater than the minimum detection limit of the analytical method, and ideally should be in the range of maximum accuracy and precision. Adjustments to the amount collected can be made by appropriately increasing or decreasing the sampling rates.

Now for the measurement of the inside concentration. If the respirator is functioning properly, the amount of contaminant collected inside the respirator should be

SUBSTANTIALLY LOWER THAN THAT FOUND OUTSIDE THE RESPIRATOR. CHANCES ARE, ONE WILL BE COLLECTING SAMPLES THAT WILL BE NEAR OR BELOW THE MINIMUM DETECTION LIMIT. TO ESTABLISH WHETHER THE ANALYTICAL/SAMPLING METHOD HAS SUFFICIENT SENSITIVITY, ONE NEEDS TO RELATE THREE PIECES OF INFORMATION:

- FIRST THE MAXIMUM VOLUME THAT CAN BE SAMPLED.

- NEXT THE PROTECTION FACTOR RANGE TO BE MEASURED. THIS CAN BE REPRESENTED BY A SINGLE NUMBER THAT IS THE MAXIMUM PROTECTION FACTOR YOU WOULD LIKE TO BE ABLE TO MEASURE. (FOR EXAMPLE, A PROTECTION FACTOR RANGE OF 1000 MEANS YOU WOULD WANT TO BE ABLE TO QUANTIFY PROTECTION FACTORS FROM 1 TO 1000.

- AND, THIRD THE WORKPLACE CONCENTRATION.

WE HAVE FOUND THAT FOR THE SAMPLE TAKEN INSIDE THE RESPIRATOR THE MAXIMUM SAMPLE RATE PRACTICAL IS ABOUT 4 LITERS PER MINUTE (THIS IS THE SAMPLE RATE USED IN SOME QUANTITATIVE FIT TEST UNITS). USING THIS RATE (OR ONE APPROPRIATE TO YOUR METHOD) AND THE LENGTH OF TIME THE RESPIRATOR WILL BE WORN ONE CAN CALCULATE THE MAXIMUM AIR VOLUME THAT CAN BE SAMPLED.

THE PROTECTION FACTOR RANGE TO BE STUDIED DEPENDS ON THE TYPE OF RESPIRATOR: HALF MASK, FULL-FACE, ETC., AND PERHAPS THE RANGE OF PROTECTION FACTORS YOU EXPECT. WE WOULD LIKE TO BE ABLE TO MEASURE PROTECTION FACTORS WHICH ARE AT LEAST 10 TIMES THE ALLOWED PROTECTION FACTOR FOR THE RESPIRATOR TYPE (FOR EXAMPLE A HALF MASK RESPIRATOR HAS AN ALLOWED PROTECTION FACTOR OF 10, SO 10 TIMES THIS IS 100.

COMBINING THIS INFORMATION WITH THE WORKPLACE CONCENTRATION LEVELS, DETERMINES THE MINIMUM DETECTION LIMIT NECESSARY FOR THE ANALYTICAL METHOD. I WILL USE AN EXAMPLE TO SHOW HOW THIS IS DONE:(2)

ASSUMING A SAMPLING RATE OF 4 LPM AND A RESPIRATOR WEARING TIME OF 1 HOUR, THE MAXIMUM VOLUME OF AIR COLLECTED IS THEN 240 LITERS OR .24 CUBIC METERS.

WE ARE USING A HALF-MASK RESPIRATOR AND WANT TO BE ABLE TO MEASURE AT LEAST 10 TIMES ITS ALLOWED PROTECTION FACTOR OF 10 OR 100.

THE WORKPLACE CONCENTRATION OF CONTAMINANT HAS BEEN MEASURED AS 25 MILLIGRAMS PER CUBIC METERS.

THE ANALYTICAL MINIMUM DETECTION LIMIT NECESSARY IS FOUND BY DIVIDING THE WORKPLACE CONCENTRATION (25 MILLIGRAMS PER CUBIC METERS) BY THE PROTECTION FACTOR RANGE (100) AND MULTIPLYING THIS RESULT BY THE MAXIMUM VOLUME OF AIR (.24 M^3) = 0.06 MG.

THE ANALYTICAL RANGE REQUIRED IS NOW DEFINED BY THIS MINIMUM DETECTION LIMIT AND THE DETECTION LEVEL ASSESSED FOR THE OUTSIDE SAMPLE. THIS RANGE CAN BE AS SMALL AS A FACTOR OF 4 TO 10,000 DEPENDING ON THE PROTECTION FACTOR RANGE NEEDED AND FLEXIBILITY IN SAMPLE SIZE TAKEN.

ONCE YOU HAVE ASSESSED THE REQUIRED SENSITIVITY, RANGE, AND KNOWN INTERFERENCES THEN THE MOST APPROPRIATE SAMPLING AND ANALYTICAL METHODS CAN BE CHOSEN. EXAMPLES OF THE TYPE OF OPTIONS AVAILABLE MIGHT BE ANALYZING FOR LEAD USING FLAMLESS ATOMIC ABSORPTION SPECTROSCOPY INSTEAD OF FLAME, IF MORE SENSITIVITY IS NECESSARY, OR SWITCHING FROM FLAME IONIZATION DETECTION FOR THE GAS CHROMATOGRAPH ANALYSIS OF CHLOROFORM ($CHCl_3$) TO AN ELECTION CAPTURE DETECTION FOR INCREASED SENSITIVITY.

THE NEED TO DO THE PRELIMINARY WORK, WHICH I HAVE JUST DESCRIBED, CANNOT BE OVEREMPHASIZED. IT IS FUTILE TO TAKE MANY SAMPLES AND THEN FIND THAT THE ANALYTICAL METHOD IS NOT AS SENSITIVE AS DESIRED.

ONCE PRELIMINARY WORK HAS BEEN COMPLETED AND A SUITABLE AREA HAS BEEN FOUND FOR CONDUCTING THE WORKING PROTECTION STUDY DATA COLLECTION MAY BE UNDERTAKEN. QUALITY CONTROL IS IMPORTANT BOTH IN THE ANALYTICAL METHOD AND IN THE SAMPLING PROCEDURE. THE ANALYTICAL QUALITY CONTROL MAY BE

CHECKED BY SUBMITTING SPIKED SAMPLES CONTAINING KNOWN CONCENTRATIONS. FOR EXAMPLE, MAKE UP A SOLUTION OF KNOWN CONCENTRATION AND PUT THIS ON FILTERS WHICH ARE SUBMITTED ALONG WITH THE OTHER SAMPLES. IN ADDITION, AREA SAMPLING SHOULD BE PERFORMED IN TRIPLICATE ALONG WITH THE PERSONAL SAMPLING. THESE SHOULD BE LOCATED IN A STABLE AREA SO THAT EACH SAMPLE WILL SEE THE SAME LEVEL OF AIR CONTAMINATION. AT LEAST ONE BLANK SHOULD BE SUBMITTED WITH EVERY TEN SAMPLES. IN ADDITION, ALL OTHER GOOD SAMPLING PRACTICES SUCH AS CALIBRATING THE SAMPLE PUMPS, SHOULD BE FOLLOWED.

THE WORKING PROTECTION FACTOR SAMPLING PROCEDURE INVOLVES TAKING TWO SAMPLES PER EMPLOYEE FOR THE ENTIRE TIME THAT THE RESPIRATOR IS WORN IN THE WORK AREA. TO DATE, SAMPLING HAS ONLY BEEN DONE USING FILTER CASSETTES. IF CHARCOAL TUBES OR PASSIVE DOSIMETERS ARE TO BE USED, THE EFFECT OF THE HIGH RELATIVE HUMIDITY FROM THE SUBJECTS BREATH ON SAMPLING SHOULD BE WELL STUDIED. ONE FILTER CASSETTE IS HOOKED TO A RESPIRATOR WHICH IS PROBED AS IF IT WERE TO BE USED FOR A QUANTITATIVE FIT TEST.(3) A CASSETTE COUPLER IS ATTACHED TO THE PROBE USING A SMALL PIECE OF TUBING AND THE CASSETTE IS ATTACHED TO THE COUPLER. (AS MENTION EARLIER, THE FLOW MAY BE SET HIGHER THAN NORMAL SAMPLING RATES TO MAXIMIZE THE AMOUNT OF MATERIAL COLLECTED ON THE FILTER.)

THE SECOND FILTER CASSETTE IS LOCATED IN THE EMPLOYEES BREATHING ZONE. PLACEMENT IS THE SAME AS NORMAL PERSONAL SAMPLING. THE FLOW MAY BE SET SLOWER TO PREVENT OVERLOADING THE FILTER.(4)

DATA COLLECTION MUST BE DONE CAREFULLY. PUMPS SHOULD BE TURNED OFF BEFORE THE RESPIRATORS ARE REMOVED. EMPLOYEES SHOULD BE INSTRUCTED NOT TO REMOVE THEIR RESPIRATOR DURING THE SAMPLING PROCESS. THIS ENSURES THAT ALL MATERIAL COLLECTED IN THE INSIDE RESPIRATOR SAMPLE HAS ENTERED THROUGH THE FACE TO RESPIRATOR SEAL. PEOPLE CONDUCTING THE STUDY MUST REMAIN IN THE AREA AND OBSERVE THE EMPLOYEES BEING SAMPLED. THIS WILL BE USEFUL IN EVALUATING THE PROTECTION FACTORS.

QUANTITATIVE FIT TESTING IS NOT NECESSARY BUT DOES PROVIDE ADDITIONAL INFORMATION. IF QUANTITATIVE FIT TESTING IS USED, IT IS DONE BEFORE AND AFTER THE WORK TASK IS PERFORMED. THE SAME PROBED RESPIRATOR USED IN THE FIT TESTING IS ALSO USED IN THE FIELD. HIGH EFFICIENCY CARTRIDGES ARE REQUIRED FOR QUANTITATIVE FIT TESTING. IT IS ADVISABLE TO USE THE SAME CARTRIDGES FOR THE FIT TESTING AND THE WORKPLACE SAMPLING. IF DUSTS, FUMES, OR MISTS ARE BEING COLLECTED, USE HIGH EFFICIENCY CARTRIDGES. IF THE CONTAMINANT IS AN ORGANIC VAPOR, USE A COMBINATION ORGANIC VAPOR, HIGH EFFICIENCY CARTRIDGE.

AT THIS TIME, ONLY PRELIMINARY DATA HAS BEEN CONDUCTED AND WE ARE UNABLE TO DRAW CONCLUSIONS. I WOULD LIKE TO DISCUSS SOME OF THE RESULTS.

ONE PRELIMINARY STUDY SAMPLED IN A PAINT SPRAYING OPERATION WHERE EMPLOYEES WORE HALF-MASK RESPIRATORS EQUIPPED WITH SPRAY PAINT FILTERS. PROTECTION FACTORS RANGED FROM 34 TO 59. EXAMINATION OF THE SITUATION SHOWED THAT THE FILTERS ARE DESIGNED TO BE APPROXIMATELY 97% EFFICIENT. AS 3% OF THE PARTICLES MIGHT BE LET THROUGH THE FILTER, THE PROTECTION FACTOR WOULD BE AROUND 100 DIVIDED BY 3, OR 33. A CHANGE WAS MADE TO HIGH EFFICIENCY FILTER CARTRIDGES AND THE PROTECTION FACTORS RANGED FROM 270 TO 1700. ALL PEOPLE SAMPLED HAD – PROTECTION FACTORS GREATER THAN 100 WHEN QUANTITATIVELY FIT TESTED.

IN CONCLUSION, WE FEEL THAT RESPIRATORS CAN PROVIDE ADEQUATE PROTECTION IF THEY ARE USED IN A GOOD PROGRAM WHICH INSISTS THAT THEY BE WORN PROPERLY. HOWEVER, A DATA BASE IS NEEDED TO PROVE THAT THIS IS TRUE.

IT ALSO SHOULD BE POINTED OUT THAT THE WORDS "WORKING PROTECTION FACTOR" MEAN MORE THAN THE PROTECTION FACTOR ACHIEVED IN A WORKING SITUATION. IT ALSO IMPLIES THAT IT CAN BE A LOT OF WORK TO CONDUCT THE STUDY, ESPECIALLY IN THE PRELIMINARY SELECTION OF AN APPROPRIATE AREA. HOWEVER, WE FEEL THAT THIS IS IMPORTANT WORK AND WE WILL BE CONTINUING TO COLLECT DATA.

DRAFT

$$WPF = \frac{C_o\ (TWA)}{C_i\ (TWA)}$$

SLIDE #1

Assessment of the Minimum Detection Limit Required (MDL_{REQ})

Maximum Sample Volume (V_{MAX})
Protection Factor Range ($P.F._{RANGE}$)
Workplace Concentration (C_o)

V_{MAX} = 4 Lpm × 60 min. = 240L

$P.F._{RANGE}$ = 10 × 10 = 100

C_o = 25mg/m³

$$MDL_{REQ} = \frac{C_o}{P.F._{RANGE}} \times V_{MAX} = \frac{25mg/m^3}{100} \times 0.24m^3 = 0.06\ mg$$

SLIDE #2

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SLIDE #3

SLIDE #4