IN-DEPTH SURVEY REPORT

CONCENTRATION OF METALWORKING MISTS BEFORE AND AFTER INSTALLATION OF A COMMERCIAL AIR CLEANER

AT

SAUER-SUNDSTRAND COMPANY
Ames, Iowa

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PLANT SURVEYED	Sauer-Sundstrand Company 2800 E 13th Street Ames, Iowa 50010
SIC CODE	3594
SURVEY DATES	June 8 - 14, 1995 August 1- 3, 1995 August 19-22, 1996
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ABSTRACT

This study evaluated the ability of commercially available air filtering cleaners installed on more than 25 machining centers to control mist emissions and to reduce workers' mist exposure In a machining center used to produce transmission parts, a mist of synthetic metalworking fluid (MWF) was generated as a result of drilling and tapping holes at rotational speeds of 1000 to 3000 rpm The MWF was flooded over the parts at 80 psi during most machining operations To facilitate metal chip removal during some operations, MWF was pumped through the orifices in some tools at a pressure of 800 psi These machining operations were performed in nearly complete enclosures that were exhausted to air cleaners, whose fans moved approximately 2400 cfm of air

To evaluate air cleaner performance, the concentration of triethanolamine and total particulate were measured before and after the installation of the air cleaning units Area concentrations were reduced from a high of 0 48 mg/m^3 to 0 04 mg/m^3 or less The total particulate concentrations on the personal samples showed a four-fold decrease from 0 22 mg/m^3 to 0 06 mg/m^3

An aerosol photometer (HAM, ppm, Inc , Knoxville, TN) and video monitoring were used to identify peak exposures to machine operators in the course of their work Peaks occurred when operators entered or partially entered the machining center enclosures Some sources of increased air contamination were identified by use of an eight-channel optical particle counter (Portable Dust Monitor, Model 1105, Grimm Ainring, Germany), the most significant sources were partially or unenclosed machining centers and inadequately covered flumes returning the MWF to the Hydromation (fluid recirculation and filtration) unit

A quartz crystal microbalance cascade impactor (model PC2, California Measurements, Sierra Madre, CA), and eight-stage particle fractionating samplers (1 ACFM Ambient Particle Sizing Sampler, Anderson Samplers, Inc , Atlanta, GA) showed that particles larger than 9 µm were present in the plant environment This suggests that besides the machining centers tested, there were other relatively minor sources of particulate such as uncontrolled machining operations

INTRODUCTION

Sauer-Sundstrand Company is a metalworking plant located in Ames, Iowa In this location, there are approximately 300 employees in the production area and approximately 200 employees in the office area Sauer-Sundstrand continues production 24 hours a day, with most production area employees working a 10 hour shift and a 40 hour week Transmissions are produced for off the road vehicles such as lawn mowers and agricultural equipment The iron castings which are brought in the plant are pre-shaped for the transmission Additional metalworking is performed on the piece, including milling and drilling Each metalworking station is automated One operator programs and tends several machines

Metalworking fluid (MWF) is also referred to as coolant, and the two terms will be used interchangeably throughout the text It is used during the metalworking to remove metal shavings and to serve as a coolant and lubricant At the metalworking stations examined in this study, the MWF was flooded onto the parts at a pressure of 80 pounds per square inch (psi) During some machining operations, the coolant is forced through small holes in the drills at higher pressures ranging between 600 to 850 psi The high pressure application of fluid was used during approximately 30 percent of the machining cycle In other machines, other coolant applications may reach pressures as high as 1200 psi During the high pressure application of coolant, the tooling rotations reached as high as 4500 rpm, with an average of approximately 1000 rpm The lower pressure applications flooded the part with the fluid at relatively low pressures, around 80 psi, approximately 70 percent of the machining cycle The bottom of the machining center has a sloped bottom where the excess fluid and debris are removed via a screw feeder leading to the fluid recycle system In the L-shop, the area studied during this survey, fluid is recycled through the Hydromation unit, which is used to pump and filter the fluid, removing metal chips and other debris The Hydromation unit storage pit has a volume of 10,000 gallons The fluid used in the L-shop at approximately 12 stations was Syntilo® 9902 (Castro Industrial, Inc , Downers Grove, IL), a synthetic product primarily composed of water and triethanolamine Several different types of MWF are used throughout the plant at approximately 250 metalworking stations

The main focus of this study was L-shop where it was thought that the majority of plant metalworking fluid mists were generated In L-shop, metalworking was performed on items with a low volume total to be produced High quantity orders were done elsewhere in the plant There were 12 stations in L-shop with approximately 45 employees These machining units were all partially enclosed and automated

Study Objectives

Sauer-Sundstrand Company requested that NIOSH researchers perform an evaluation on the efficacy of a commercially available air cleaner This air cleaner would be placed downstream from a metalworking station, and the "cleaned" air would be recirculated into the plant, thus saving heating and cooling costs The recirculation would also eliminate the need for an exhaust stack for the numerous stations, also, there are significant time-delays associated with obtaining stack permits from local air pollution control agencies In order to meet production demands and to save money, the air is circulated through an air cleaner and the discharged air is recycled to the plant Thus, there is a need to evaluate the efficacy of air cleaners for removing MWF mists Sauer-Sundstrand hoped to gather additional information in order to decide if this type of air cleaner should be installed throughout the plant on each of the metalworking stations One of NIOSH's goals for conducting this in-plant study was as a prelude to future pilot plant studies to evaluate the effect of machining parameters upon size dependent mist concentrations The main issues to be examined included the following

- Establish the efficacy of this air cleaner for reducing worker exposure to MWF Three surveys were conducted to gather this information The first study was conducted in June 1995 to experimentally evaluate the test stand designed and built by NIOSH researchers in order to characterize the aerosol, this initial evaluation is referred to as "Phase 1 " During the second evaluation, conducted in August 1995, air contaminant concentrations were measured This part of the project is referred to as "Phase 2 " The NIOSH report,[1] "Characterization of Metalworking Mists During the Evaluation of a Commercial Air Cleaner," ECTB-218-11a, April 25, 1996, presents the findings for "Phases 1 and 2 "

- Show reduction in airborne concentrations of TEA and total particulate after installation of more than 25 air cleaners in and near the L-shop area of the plant This survey was conducted in August 1996 and is referred to as "Phase 3 "

- Identify specific operations that showed higher worker exposures by video exposure monitoring (with an aerosol photometer-HAM) and locate and identify major sources of MWF mists by use of a direct reading instrument (an optical particle counter-Grimm)

- Determine size distribution of particulate in plant atmosphere by impaction (both eight stage inertial and quartz crystal microbalance) Particles larger than 3μm indicate that not all emission sources have been controlled

Health Effects

There are many health effects associated with metalworking exposures including dermatitis,[2] respiratory disease,[3] and asthma[4] Cross-shift decrements in lung function are reported for inhalable aerosol exposures larger than 0 2 mg/m^3 [3] Microbial contamination and endotoxins (debris from dead microbes) may also be responsible for adverse pulmonary health effects[3] Some on-going research has suggested that lifetime exposures to specific types of metalworking fluids (straight, soluble, and synthetic) are associated with several digestive cancers[5] For these reasons, it is prudent to control exposures to metalworking fluids

Exposure Evaluation Criteria

Triethanolamine is the major component of the synthetic MWF used during this study For triethanolamine, the American Conference of Governmental Industrial Hygienists (ACGIH) has established a Threshold Limit Value (TLV) of 5 mg/m^3 as an 8-hour time weighted average [6] The ACGIH is a private organization and its TLVs refer to airborne concentrations to which nearly all workers may be repeatedly exposed without experiencing adverse health effects

The Occupational Safety and Health Administration (OSHA) has established a permissible exposure limit for particulate not otherwise regulated of 15 mg/m^3 as an 8-hour time weighted average [7]

Air Cleaner Description

The air cleaner installed is shown in Figure 1 It is a packaged air filter unit, Model F120, manufactured by Airflow Systems, Inc (Dallas, TX) with an approximate cost of $4[illegible]00 The units were installed over the metalworking stations and pulled the air into the cleaning units The air cleaner's fan moved approximately 2400 cfm through the enclosure The air cleaner is equipped with a metal mesh prefilter, followed by a pleated "mist eliminator" prefilter Next are the main filters, which are 95 percent efficient ASHRAE pocket filters According to ASHRAE guidelines, a 95 percent efficiency filter removes all particles with a diameter of approximately 2 μm The fractional efficiency curve of this filter also shows a minimal efficiency of approximately 72 percent for particles sized near 0 3 μm [8] The fluids captured by the filters drip to the floor of the cleaner and exit via three drainage holes The coolant then drains to the Hydromation recycling system At the outlet of the cleaner, is a 4-way adjustable grill for the exiting air

Modifications to the Air Cleaner After Phase 2

During Phase 2 of the study, it was noted that the three air cleaner drains were clogging, perhaps entraining additional MWF mist into the air flow As a result, the facility maintenance personnel enlarged the drains from 0 5 inches to 1 inch in diameter to allow proper drainage Plastic translucent tubing was added to the drains, leading to a goose neck fitting which led, ultimately, to the Hydromation unit The translucent tubing showed if there was fluid draining and would indicate if there was blockage Also, the air cleaner was tilted slightly so that it sloped toward the drains instead of the fan Maintenance personnel reported that the exhaust grill remained clean

Air Cleaner Maintenance

A maintenance program was established for the installed air cleaners Each air cleaner was fitted with an aneroid pressure gauge to indicate pressure drop across the system It is not permitted to exceed 2 inches w g The filters are changed at 30 day intervals and thoroughly cleaned or

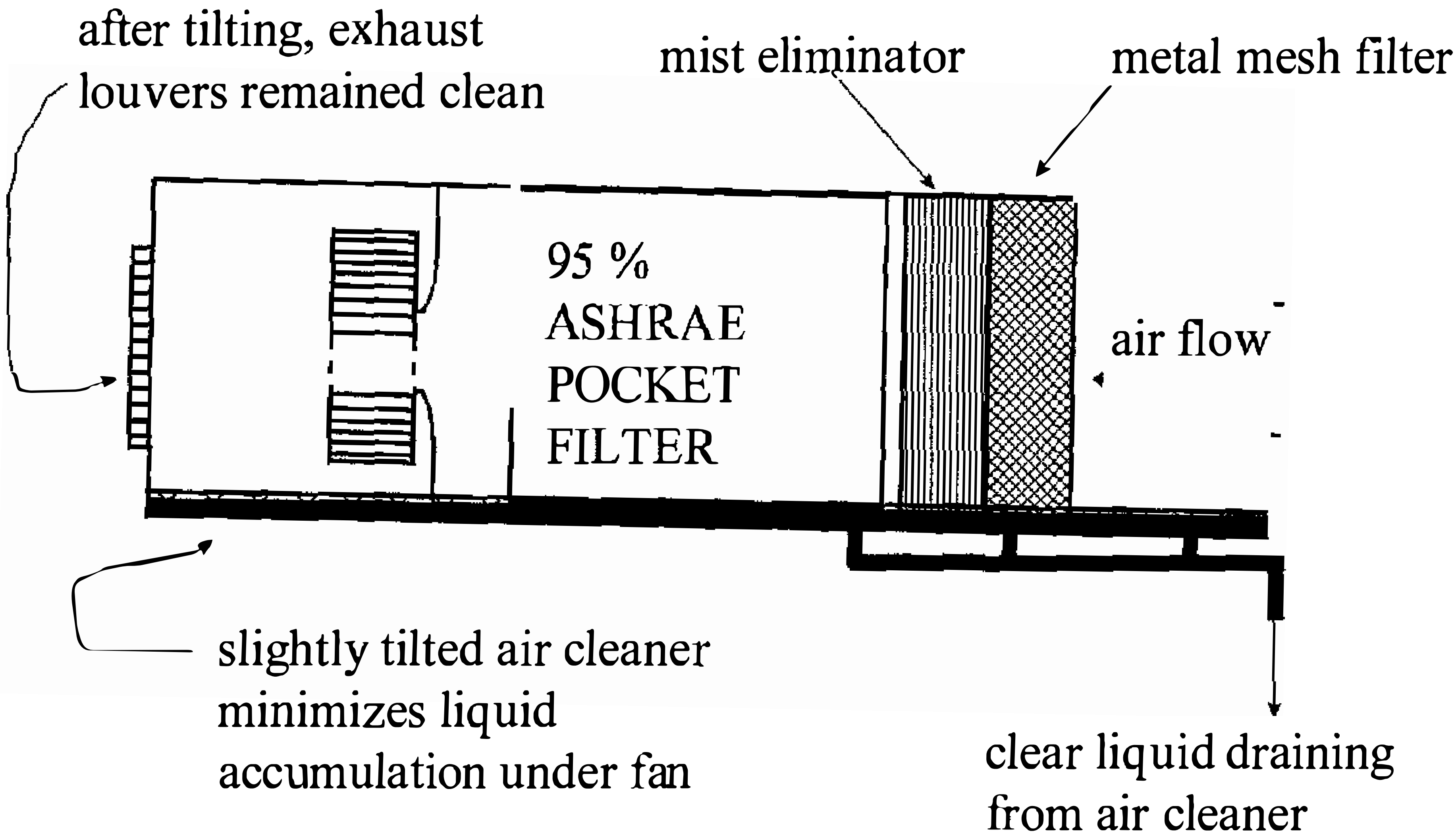

Figure 1 Installed air cleaner with incline and larger diameter drains, modifications made following qualitative observations of MWF accumulation noted during the second phase of the study

replaced Because the MWF tends to collect in the filters and not fully drain when a machining center is run on a 24 hour per day cycle, the air cleaners on these machines are turned off, i e , rested for 1 hour out of each 24 hours This "rest cycle" is not necessary for the machining centers that are run for 8-to-10 hour periods each 24 hours With the exception of the "rest cycle," the maintenance program appears to be conservative and may help to explain the low concentrations measured

Instrumentation

The instruments below were used during sampling

- The Portable Dust Monitor (PDM), (Model 1 105, Grimm Labortechnick GmbH&Co, Ainring, Germany)

  The PDM is an optical particle counter, which samples air at a flow rate of 1 2 liters per minute The PDM counts individual particles and classifies particles based upon the amount of light scattered by the individual particle This instruments' RS-232 output lists the number of particles larger than 0 75, 1 0, 2, 3 5, 5, 7 5, 10, 15 μm and the time

- Piezoelectric Quartz Crystal Microbalance (QCM) Cascade Impactor (Model PC-2, California Measurements Inc, Sierra Madre, CA)

  The QCM draws 0 25 lpm of air through a series of progressively smaller jets which forces the air to flow around piezoelectric crystals which sense the mass collected after each impaction jet As the diameter of the jets decreases, the air velocity increases, and particles with smaller aerodynamic diameters are collected on the piezoelectric sensors The vibration frequency of these crystals is measured The changes in the vibrational frequency is used to compute the mass of aerosol collected on each impaction stage The particle diameter for which an impaction stage is 50 percent (by mass) efficient is termed the 50 percent cut-off diameter (D_{50}) There is some disagreement between the theoretically estimated and experimentally determined values of D_{50} determined by Fairchild and Wheat [9] In analyzing the data, their experimental data was used These data are shown in Table 1 This instrument is used to take short term samples (30-900 seconds) The sampling time was varied in order to collect measurable masses of aerosol on the impaction surfaces without overloading the piezoelectric crystals

- Aerosol Photometer - Handheld Aerosol Monitor (HAM), (ppm, Inc , Knoxville, TN) The HAM continuously sampled the air from the operator's breathing zone The HAM was operated on the 0-2 mg/m^3 range and at a time constant of 1 second In the instruments sensing chamber, the HAM measures the quantity of light scattered by the entire cloud The quantity of scattered light is a function of concentration and the aerosol's optical properties Thus, this instrument's response is a measure of relative

Table 1. Theoretical and Experimental Values of D_{50} for Unit Density Spheres for California Instruments QCM Obtained by Fairchild and Wheat[9]

Stage	Theoretical (μm)	Experimental (μm)
1	24	17
2	9 4	13
3	9 2	9
4	4 6	3 9
5	2 3	1 8
6	1 3	1 2
7	0 62	0 64
8	0 4	0 34
9	0 23	0 26
10	0 14	0 14

concentration The analog output of this instrument was recorded using a data logger (Metrasonics, Inc , Rochester, NY)

- Particle Fractionating Sampler/Impactor-1 ACFM Ambient (Anderson 2000), (Anderson Instruments, Inc , Atlanta, GA)

  The Anderson 2000 is an 8-stage cascade impactor that was operated at a flow rate of 1 CFM The MWF mist was collected on 81 mm tared glass fiber filters The size range of the stages are, in µm 9 0 and above, 5 8-9 0, 4 7-5 8, 3 3-4 7, 2 1-3 3, 1 1-2 1, 0 7-1 1, 0 4-0 7, and backup filter These filters were pre- and post-weighed in a temperature and humidity controlled environment

EXPERIMENTAL PROCEDURES - PHASE 3

Impinger samples were taken using NIOSH Method 3509 for triethanolamine (TEA)[10] Pump flow rates were increased to 2 lpm The limit of detection (LOD) was 9 μg/sample and the limit of quantitation (LOQ) was 29 μg/sample There were no samples reported as nondetectable Samples which were found to be between the LOD and LOQ were estimated with the analytical laboratory reported result

Impinger sampling was only used for area samples Samples were taken in several areas, including "between machines" for 4-8 hour periods Two other sites were chosen because they were at opposite boundaries of the L-shop, the samples were denoted as "L-Shop Edge" and near the Hydromation unit (Hydro), "central cleaning "

Personal and area samples for total weight particulate were taken according to NIOSH Method 0500 [10] Area samples were taken at the same locations as for impinger samples In addition, samples were collected on the workers in the area Other than blanks, there was only one sample which resulted in a nondetectable level For statistical purposes, this sample was estimated to be LOD/2, or 0 01 mg/sample

Two operators were monitored by an aerosol photometer, handheld aerosol monitor (HAM) manufactured by ppm, Inc The unit was belt mounted and the operators were videotaped as they performed various tasks including machining center adjustment and cleaning, re-mounting castings on "tombstones," checking specifications of machined castings inside a plant floor enclosed room, and making adjustments on partially enclosed machining centers See Figure 2 for the plant floor layout and approximate locations of peak measurements

The Portable Dust Monitor (PDM), an optical particle counter, manufactured by Grimm was used at six locations inside the plant shop areas (see Figure 2), the front office area on the first floor, and outside the main employee entrance Total particulate concentration was reported

The quartz crystal microbalance cascade impactor (QCM) manufactured by California Instruments was used in several locations to determine the particle size distribution in the plant atmosphere Measurements were made near the "central cleaning" (Hydro) unit and "between machining centers "

Two eight-stage inertial impactors (Anderson), with no preseperators, coupled with one CFM pumps were used to collect size distributed total particulate in the same two plant locations sampled with the QCM, the impingers, and the filter cassettes Total particulate was collected continuously for nearly three full days, including the one hour per day during the night shift that the air cleaners were turned off to allow the filter elements to gravity drain

RESULTS AND FINDINGS

TEA and total particulate concentrations measured during Phase 3 are listed in Appendices I and II The impinger data for TEA, comparing concentrations measured before and after controls (air cleaners) were installed, are summarized in Table 2 and Figure 3 Similarly, the filter cassette data for total particulate are summarized in Table 3 and Figure 4 Inspection of these tables and figures shows decreases in concentrations by factors of 2 to 10 The right most

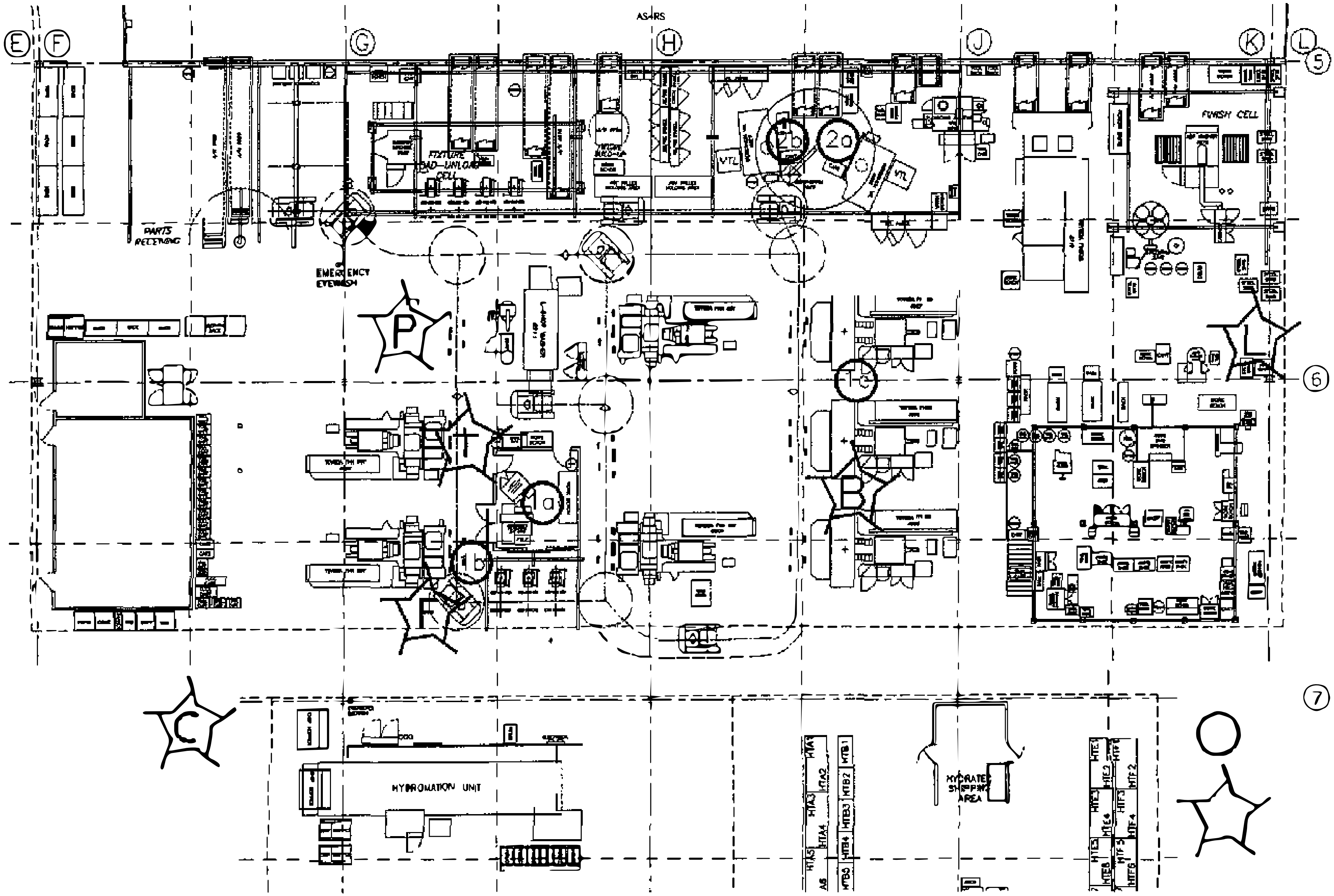

Figure 2 L-Shop floor plan showing sampling locations B is between machining centers, C is the central cleaning (Hydro) unit, F is in the flume, L is L-Shop edge, P is a partially covered flume, and T is an unventilated machining center The circled numbers indicate the video monitoring locations, 1 is for Operator A, and 2 is for Operator B

Table 2: Summary Statistics for Triethanolamine Concentrations

	August 1995			August 1996			Significance of Concentration Reduction
Location	N	GM (mg/m^3)	GSD	N	GM (mg/m^3)	GSD	Probability > F
Between Machines	5	0 25	1 34	6	0 03	1 21	0 0001
Central Cleaning (Hydro unit)	6	0 43	1 38	6	0 04	1 23	0 0001
L-Shop Edge	6	0 11	2 21	6	0 03	1 26	0 0024

N = Number of Samples, GM = Geometric Mean, GSD = Geometric Standard Deviation
Based on a one way analysis of variance (ANOVA) using log transformed data [11,12]

Table 3: Summary Statistics for Total Particulate Concentrations

	August 1995			August 1996			Significance of Concentration Reduction
Location	N	GM (mg/m^3)	GSD	N	GM (mg/m^3)	GSD	Probability >F
Between Machines	6	0 25	1 72	5	0 02	1 77	0 0001
Central Cleaning (Hydro unit)	6	0 48	1 59	6	0 03	1 33	0 0001
L-Shop Edge	6	0 07	2 20	6	0 03	2 76	0 0960
Worker (Personal)	18	0 22	1 59	16	0 06	1 50	0 0001

N = Number of Samples, GM = Geometric Mean, GSD = Geometric Standard Deviation
Based on a one way analysis of variance (ANOVA) using log transformed data [11,12]

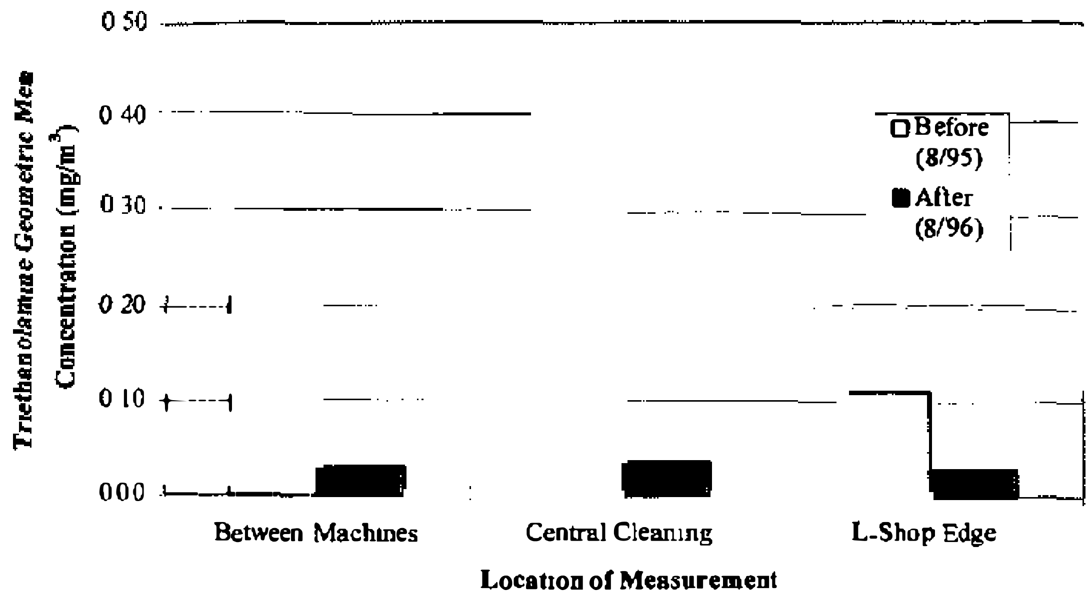

Figure 3 Triethanolamine (TEA) concentrations measured before (August 1995) and after (August 1996) installation of air cleaners in the Sauer-Sundstrand plant

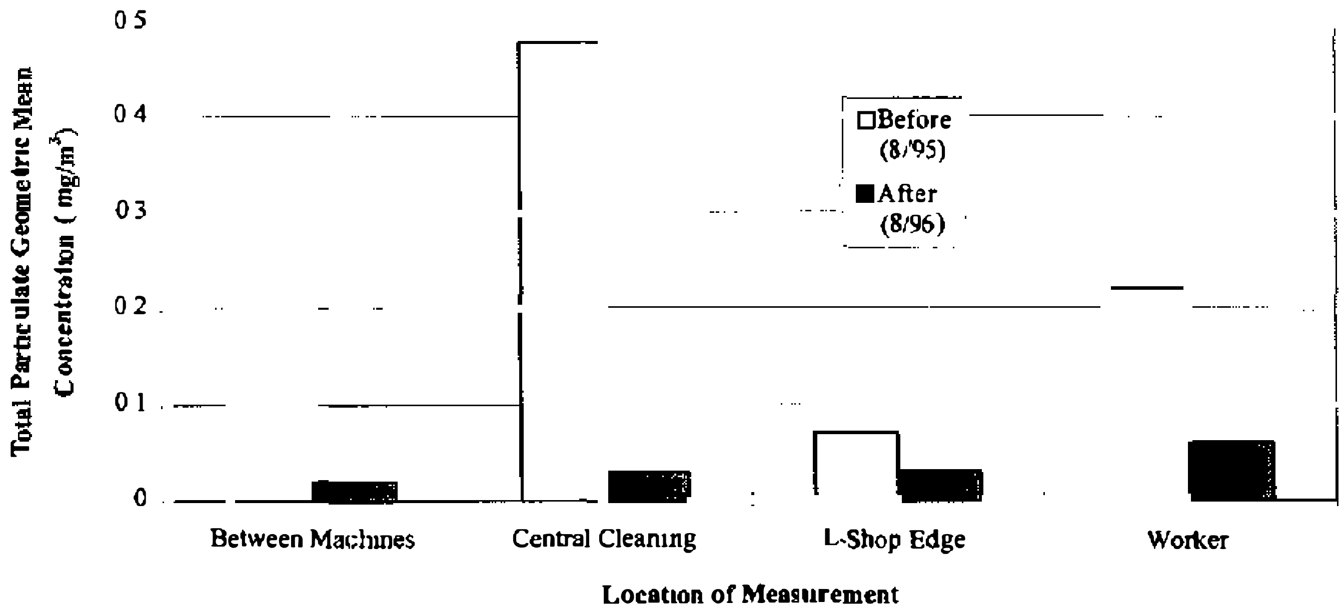

Figure 4 Total particulate concentrations measured before (August 1995) and after (August 1996) installation of air cleaners in the Sauer-Sundstrand plant

columns in the tables present the probabilities that chance could have caused the differences With the exception of the total particulate concentration measured at the "L-Shop Edge" (Table 3), these differences are all very significant Installation of controls reduced workers' personal total particulate exposure from 0 22 mg/m^3 to 0 [illegible]6 mg/m^3, however, this reduced value was higher than area concentrations measured at the "L-Shop Edge" and "between machines," based upon the Waller-Duncan k-ratio t test [12] Thus the worker engages in activities which provide some minor increase in his total particulate exposure

The results of the HAM/video-exposure monitoring are shown in Figure 5 Operator A had his highest reading, 0 93 mg/m^3, when he was inside a machining center (#4897) "cleaning," his second highest, 0 46 mg/m^3, occurred when he was inside the L-shop floor office checking specifications (tolerances) Operator B had his highest levels when he was at the open door, at times with his arm inside, partially enclosed machining centers (#6922 and #6921) The levels were 0 45 to [illegible] 63 mg/m^3

The results of the PDM (Grimm) survey are shown in Figure 6 The highest relative mist concentration levels were found in the flume near a machining center across the main isle from the Hydromation (central cleaning) unit at 22 4 mg/m^3, the lowest, outside the plant at 0 018 mg/m^3 Levels at an unventilated, partially enclosed machining center (#6902) were the next highest at 0 397 mg/m^3 followed closely by 0 284 mg/m^3 over a piece of plywood covering a floor flume where a machining center had been removed Some of the peaks shown may have nothing to do with MWF For example, in the "office conference room" there were particulate levels measured which could have been dust There are other instances of exposure causing events noted in Figure 6

The quartz crystal micro balance (QCM) cascade impactor results are shown in Figures 7 and 8

The results of the eight-stage (Anderson) impactor studies are shown in Figures 9 and 10 For the Anderson, the LOD=0 1 mg/filter and the LOQ=0 3 mg/filter The impactor located "between machining centers" yielded an overall concentration of 0 11 mg/m^3 with 30 percent of the material deposited on the first filter or stage indicating that there was a heavy concentration of large particles Without the material on the first filter, the concentration was 0 078 mg/m^3 The corresponding numbers for near the "central cleaning" (Hydro) unit are 0 14 mg/m^3, 37 percent and 0 087 mg/m^3 Aerosols larger than 3-4 μm were present indicating exposures are probably due to uncontrolled operations

DISCUSSION AND CONCLUSIONS

Phase 2 of the study indicated relatively low concentrations (less than 0 5 mg/m^3) of total particulate and TEA With both substances, the highest concentrations were found near the Hydromation (central cleaning) unit This unit was apparently causing significant emissions of metalworking fluids into the plant's air In order to reduce MWF mist concentrations throughout the plant this emission source was controlled

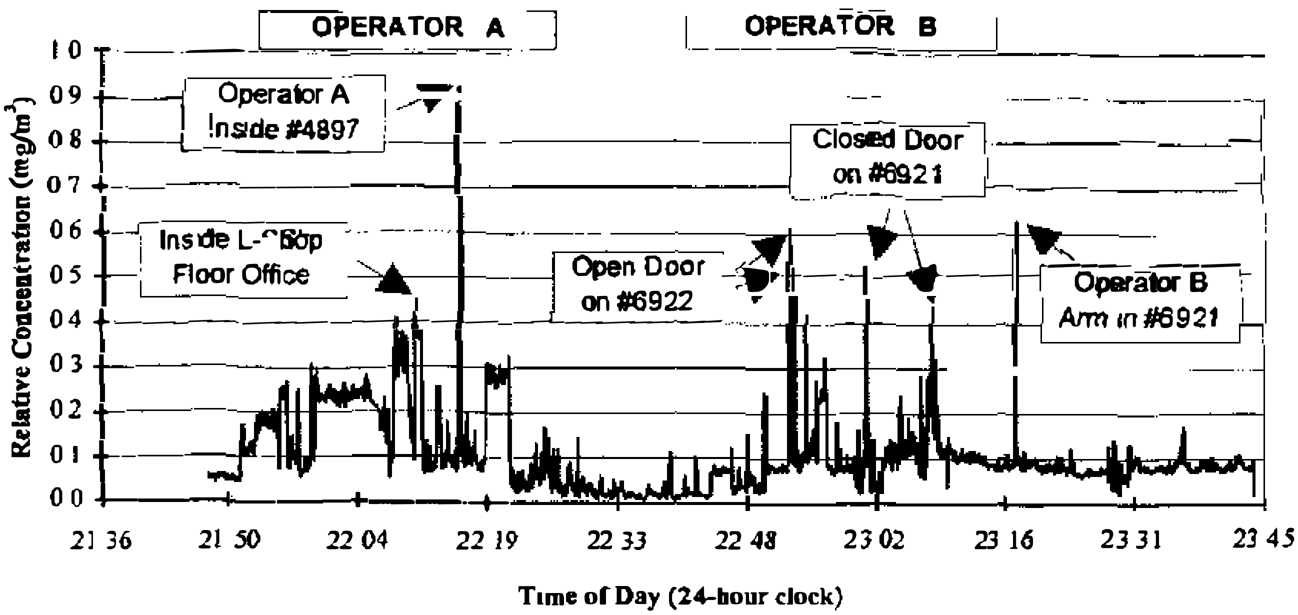

Figure 5 Particulate concentrations measured with a hand-held aerosol monitor (HAM) worn by two operators in L-Shop who were also video monitored while performing their jobs, August 1996

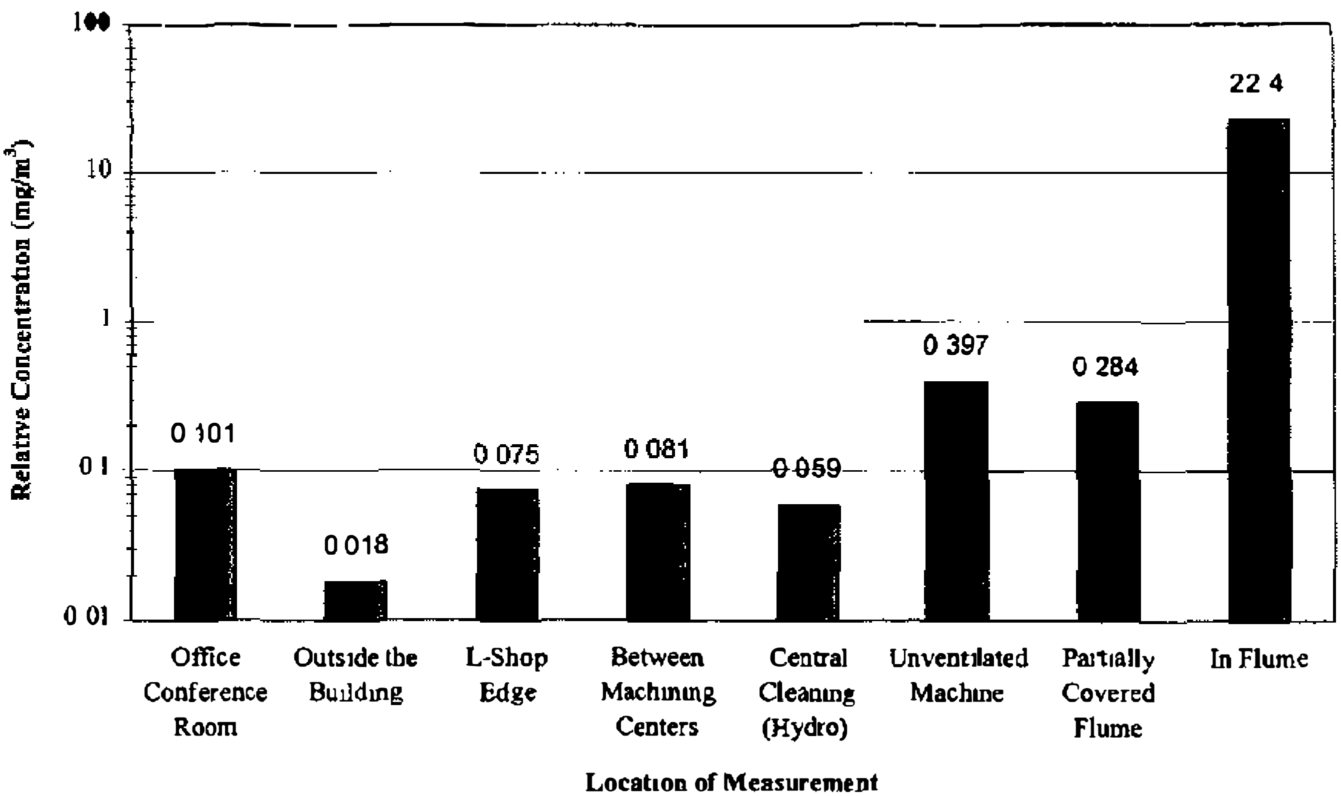

Figure 6 Total particulate concentrations measured with a Grimm portable dust monitor (PDM) in various locations in the plant and office areas and outside the plant, August 1996

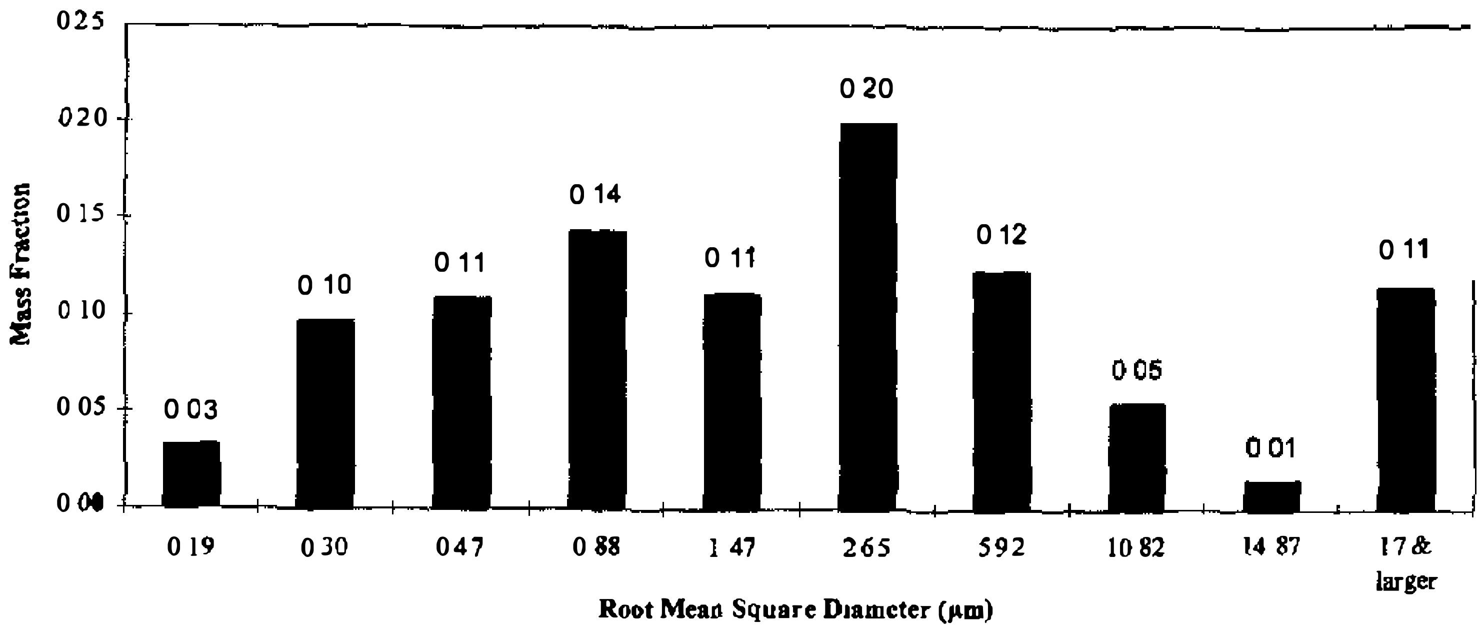

Figure 7 Total particulate near the "central cleaning (Hydro) unit"(C) collected with a quartz crystal microbalance cascade impactor, August 1996

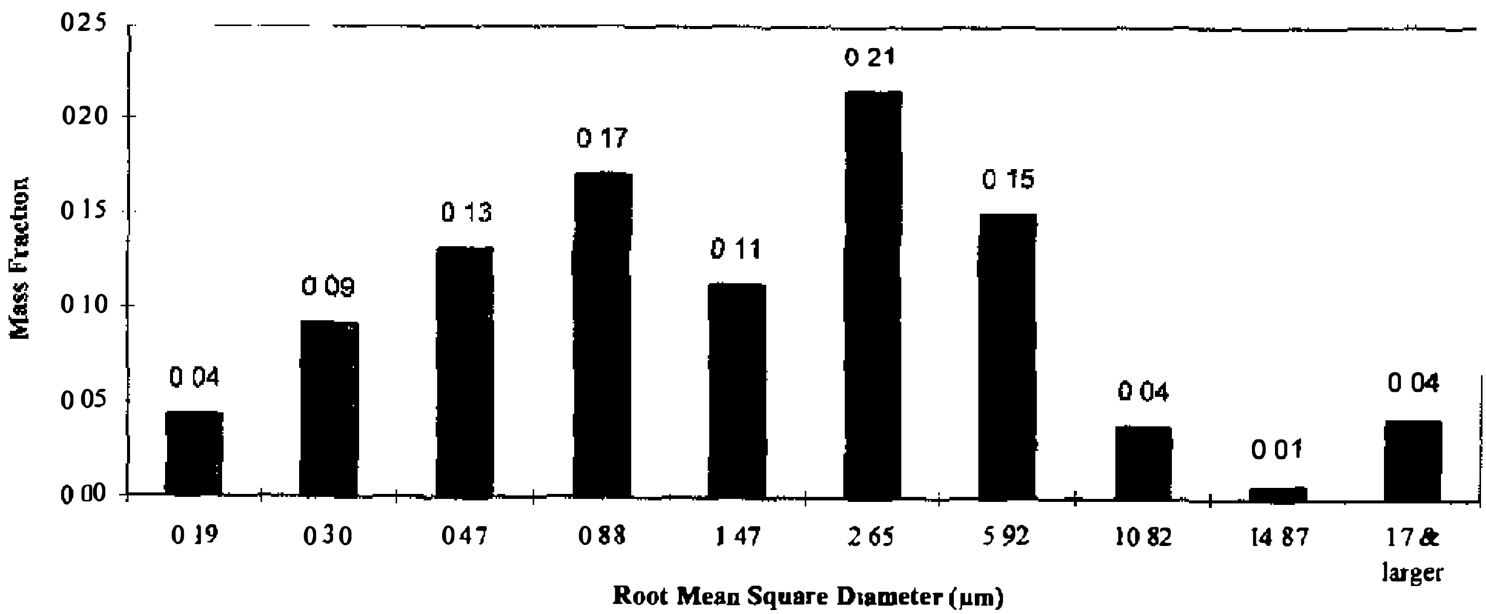

Figure 8 Total particulate "between machining centers"(B) collected by a quartz crystal microbalance cascade impactor, August 1996

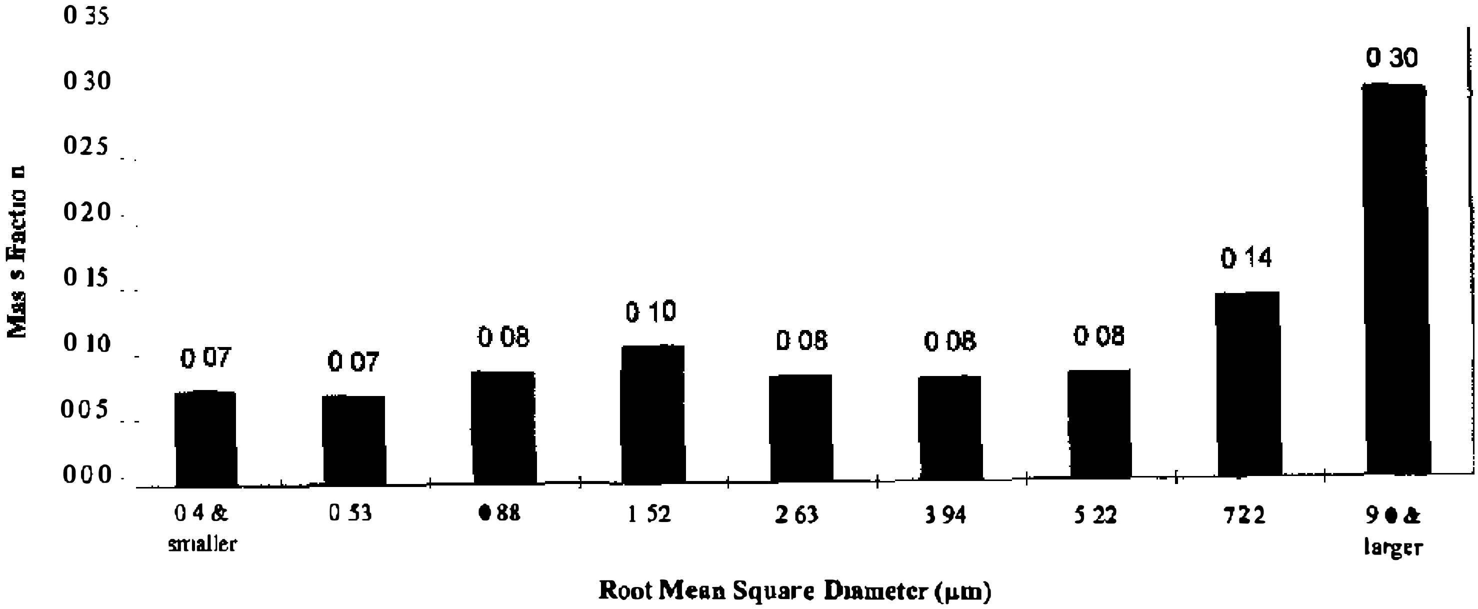

Figure 9 Total particulate "between machining centers"(B) collected by Anderson Impactor, August 1996 A total of 13 81 mg of material was collected

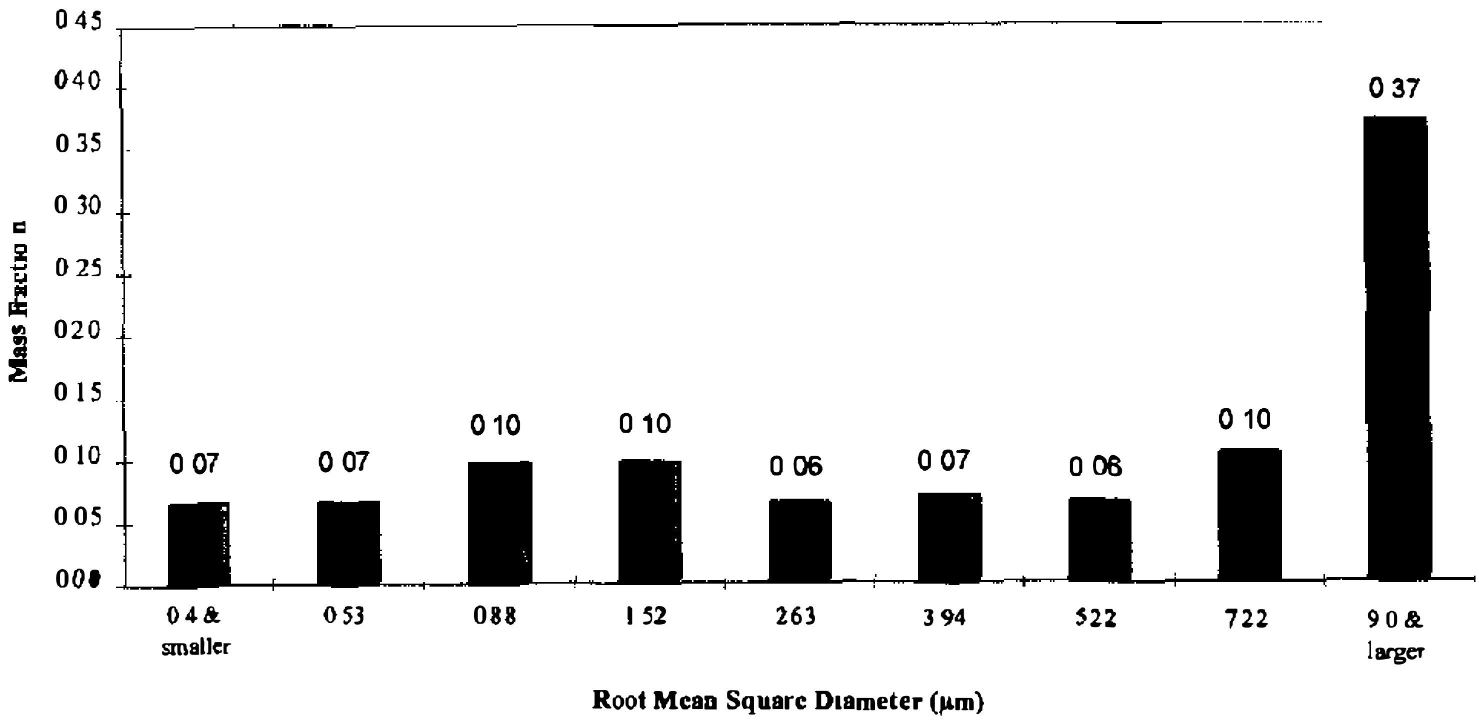

Figure 10 Total particulate near the "central cleaning (Hydro) unit"(C) collected by Anderson Impactor, August 1996 A total of 16 87 mg of material was collected

Phase 3 of the study demonstrated the effectiveness of installing air cleaners on the machining centers and improving mist control on the Hydromation unit TEA concentrations were reduced four-to-ten fold The total particulate concentrations were reduced 16 fold near the Hydromation unit, the location of highest concentration in the 'before' or Phase 2 study, and were significantly improved in the other area samples and in the personal samples

Some major sources remain, they are the older machining centers which are not so well enclosed These conditions should improve as older centers are replaced with new, more fully enclosed machining centers It remains important to continue enclosure of the flumes and as much of the Hydomation unit operation as possible The exposures to individual operators doing specific tasks were not large (less than 1 0 mg/m³) but could be decreased with improved ventilation and changes in work procedures

The impactor results showed that there are still large particles being emitted into the work environment The differences between the QCM and eight-stage studies, may indicate that the large particles are being emitted during the 1 hour air cleaner down time periods

The installation of the air cleaners has resulted in a significant reduction in the TEA and total particulate concentrations in the plant work environment

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APPENDIX I

Sauer-Sundstrand Company, Ames, Iowa 50010 August 1996 Triethanolamine Impinger Data

Date	Run	Shift	Location of Measurement	Field Sample Number	Time min	Pump Flow Rate,cc/min	Triethanolamine µg/sample	Triethanolamine mg/m^3
8/19/96	1	2nd	Between machines	1	270	2022	18	0.033
8/20/96	2	1st	Between machines	4	319	2040	22	0.034
8/20/96	3	2nd	Between machines	8	472	2022	32	0.034
8/21/96	4	1st	Between machines	11	356	2040	24	0.033
8/21/96	5	2nd	Between machines	15	464	2020	22	0.023
8/22/96	6	1st	Between machines	18	400	2035	19	0.023
8/19/96	1	2nd	Central cleaning-hydro	3	243	2007	22	0.045
8/20/96	2	1st	Central cleaning-hydro	6	324	1992	29	0.045
8/20/96	3	2nd	Central cleaning-hydro	10	472	1993	32	0.034
8/21/96	4	1st	Central cleaning-hydro	13	360	2035	29	0.040
8/21/96	5	2nd	Central cleaning-hydro	17	470	1997	25	0.027
8/22/96	6	1st	Central cleaning-hydro	20	402	1992	25	0.031
8/19/96	1	2nd	L-shop edge	2	275	1998	19	0.035
8/20/96	2	1st	L-shop edge	5	317	2035	22	0.034
8/20/96	3	2nd	L-shop edge	9	469	2000	22	0.023
8/21/96	4	1st	L-shop edge	12	353	1992	25	0.036
8/21/96	5	2nd	L-shop edge	16	471	1993	25	0.027
8/22/96	6	1st	L-shop edge	19	397	2040	17	0.021
8/20/96	2	1st	N blank	7			ND	
8/21/96	4	1st	N blank	14			ND	
8/19/96	1	2nd	N blank	blank			ND	
8/21/96	4	1st	N blank	blank			ND	
8/22/96	6	1st	N blank	deion water			ND	

LOD (Limit of Detection) = 9 µg/sample
LOQ (Limit of Quantification) = 29 µg/sample

	Geometric Mean	Geometric Standard Deviation
B near cleaner-between Toyodas	0.030	1.21
C near hydromation unit	0.036	1.23
L end L-shop at L6K6	0.029	1.26

APPENDIX II

Sauer-Sundstrand Company, Ames, Iowa 50010		August 1996		Total Particulate Data				
Date	Run	Shift	Location of Measurement	Filter Number	Time min	Pump Flow Rate,cc/min	Total Particulate mg/sample	mg/m^3
8/19/96	1	2nd	Between machines	5938	469	4018	002	0 00730
8/20/96	2	1st	Between machines	5892	491	3981	005	0 02238
8/20/96	3	2nd	Between machines	5885	431	3957	005	0 02565
8/21/96	4	1st	Between machines	5925	464	4024	-0 08	-0 04619
8/21/96	5	2nd	Between machines	5849	410	3992	003	0 01451
8/22/96	6	1st	Between machines	5902	438	4043	006	0 03035
8/19/96	1	2nd	Central cleaning-hydro	5921	471	3965	0 06	0 02878
8/20/96	2	1st	Central cleaning-hydro	5904	468	3957	0 07	0 03442
8/20/96	3	2nd	Central cleaning-hydro	5778	435	4024	0 09	0 04785
8/21/96	4	1st	Central cleaning-hydro	5901	467	4018	0 08	0 03930
8/21/96	5	2nd	Central cleaning-hydro	5843	404	3999	0 04	0 02089
8/22/96	6	1st	Central cleaning-hydro	5910	433	4018	0 07	0 03664
8/19/96	1	2nd	L-shop edge	5908	467	4024	0 02	0 00732
8/20/96	2	1st	L-shop edge	5898	490	4043	0 09	0 04228
8/20/96	3	2nd	L-shop edge	5879	430	3981	003	0 01387
8/21/96	4	1st	L-shop edge	5961	459	4024	0 06	0 02910
8/21/96	5	2nd	L-shop edge	5850	413	3965	0 06	0 03282
8/22/96	6	1st	L-shop edge	5918	438	4024	007	0 03617
8/19/96	1	2nd	Worker	5897	392	3992	009	0 05352
8/19/96	1	2nd	Worker	5920	294	3981	-0 01	-0 01388
8/19/96	1	2nd	Worker	5909	385	3999	0 12	0 07388
8/20/96	2	1st	Worker	5915	370	3973	0 08	0 05017
8/20/96	2	1st	Worker	5893	360	4018	0 22	0 14777
8/20/96	2	1st	Worker	5899	391	3976	0 12	0 07317
8/20/96	3	2nd	Worker	5880	386	4018	0 11	0 06689
8/20/96	3	2nd	Worker	5889	384	3965	0 06	0 03530
8/20/96	3	2nd	Worker	5905	379	3992	0 08	0 04875
8/21/96	4	1st	Worker	5919	362	4043	0	-0 00427
8/21/96	4	1st	Worker	5913	466	3973	0 12	0 06144
8/21/96	4	1st	Worker	5907	464	3976	0 08	0 03998
8/21/96	5	2nd	Worker	5898	448	3981	0 05	0 02453
8/21/96	5	2nd	Worker	5922	445	3973	0 08	0 04171
8/21/96	5	2nd	Worker	5881	444	3949	0 21	0 11621
8/22/96	6	1st	Worker	5840	366	4024	0 08	0 05008
8/22/96	6	1st	Worker	5857	313	3952	0 14	0 10813
8/22/96	6	1st	Worker	5870	358	3976	0 11	0 07289
8/19/96	1	2nd	N blank	5886			0	
8/19/96	1	2nd	N blank	5942			-0 02	
8/20/96	2	1st	N blank	5906			0 03	
8/20/96	2	1st	N blank	5891			0 03	
8/22/96	6	1st	N blank	5860			0 04	
8/22/96	6	1st	N blank	5890			-0 01	
8/22/96	6	1st	N blank	5833			-0 01	
8/22/96	6	1st	N blank	5924			-0 01	

Sauer-Sundstrand Company, Ames, Iowa 50010 August 1996 Total Particulate Data

Date	Run	Shift	Area (Location)	Filter Number	Time min	Pump Flow Rate,cc/min	Total Particulate mg/sample	mg/m^3
8/20/96	1	1st	Series 20 cell	5894	361	4043	0 08	0 05053
8/21/96	2	1st	Series 20 cell	5888	357	4043	0 11	0 07188
8/22/96	3	1st	Series 20 cell	5912	457	3981	0 04	0 01855
8/20/96	1	1st	Series 90 cell	5903	349	4024	0 05	0 03115
8/21/96	2	1st	Series 90 cell	5911	377	3973	0 08	0 04924
8/22/96	3	1st	Series 90 cell	5883	452	3957	0 04	0 01887
8/20/96	1	1st	Worker on 20	5900	313	4024	0 07	0 05061
8/21/96	2	1st	Worker on 20	5895	304	3981	0 12	0 09399
8/22/96	3	1st	Worker on 20	5916	83	4043	0	-0 01863
8/20/96	1	1st	Worker on 90	5923	355	3973	0 14	0 09483
8/21/96	2	1st	Worker on 90	5882	377	3957	0 16	0 10306
8/22/96	3	1st	Worker on 90	5889	452	3973	0 09	0 04664
8/19/96	1	2nd	Between machines	6246	466	25000	0 37	0 03106
8/20/96	2	1st	Between machines	6267	470	25000	0 6	0 05037
8/20/96	3	2nd	Between machines	6254	430	25000	0 45	0 04110
8/21/96	4	1st	Between machines	6263	478	25000	0 67	0 05538
8/21/96	5	2nd	Between machines	6264	408	25000	0 38	0 03645
8/22/96	6	1st	Between machines	6253	450	25000	0 51	0 04461
8/19/96	1	2nd	Central cleaning-hydro	6256	475	25000	0 6	0 04984
8/20/96	2	1st	Central cleaning-hydro	6242	467	25000	0 69	0 05840
8/20/96	3	2nd	Central cleaning-hydro	6255	435	25000	0 62	0 05626
8/21/96	4	1st	Central cleaning-hydro	6250	480	25000	0 85	0 07015
8/21/96	5	2nd	Central cleaning-hydro	6260	403	25000	0 48	0 04683
8/22/96	6	1st	Central cleaning-hydro	6247	446	25000	0 38	0 03335
			N blank	6262			-0 01	
			N blank	6245			0 01	
			N blank	6248			0 02	
			N blank	6243			0 01	
			N blank	6270			0 01	
			N blank	6241			0 02	
			N blank	6257			0 01	
			N blank	6266			-0 01	
			N blank	6251			0	
			N blank	6258			0	
			N blank	6249			0 03	

LOD (Limit of Dectection) = 0 02 mg/m^3