In-Depth Survey Report

**Control Technology Assessment
for the Welding Operations**

at

**Vermeer Manufacturing
Pella, Iowa**

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SUMMARY

The National Institute for Occupational Safety and Health (NIOSH) is currently conducting research on the effectiveness of various engineering controls to reduce arc welding fume emissions Most control measures observed in the workplace employ either general or local ventilation methods, such as canopy hoods and fume extraction guns Recent research interest has focused on the ability of process modifications to eliminate or reduce the need for ventilation during gas metal arc welding (GMAW) operations This paper relates the details of an in-depth study conducted of GMAW operations, at an agricultural and construction machinery manufacturer This company was distinct from other sites surveyed because many of the welders used pulsed inverter, rather than conventional, welding power sources According to recent literature, pulsed gas metal arc welding can result in lower fume levels than conventional gas metal arc welding because of a controlled droplet size and a lower average welding current The purpose of this study was to compare welding fume exposures from pulsed and conventional techniques during welding on low carbon steel Welding fume data (gravimetric and elemental) were collected with filter cassettes and personal sampling pumps on 29 welders Passive samplers were used to monitor personal ozone exposures since ozone levels reportedly increase during pulsed arc welding Real-time data were also collected, using an aerosol photometer and a particle counter, in combination with a videotape of the welding operation Results showed a difference existed between the two welding techniques total welding fume and elemental exposures were significantly lower during pulsed arc welding compared to conventional arc welding Ozone concentrations did not differ significantly between pulsed and conventional methods The average arc time during sampling, which is directly related to the amount of fume generated, was also not significantly different between the two methods

INTRODUCTION

In January 1997, researchers from the National Institute for Occupational Safety and Health (NIOSH) conducted an in-depth study of the gas metal arc welding operations at an agricultural and construction equipment manufacturer   The company produces heavy machinery such as trenchers, tractors, hay balers, tree handling equipment, and directional boring systems Approximately 475 welders are employed in seven independently operated plants located at the site   In the past, worker exposures to welding fumes were controlled through a combination of general and local exhaust ventilation   Recently, plant management has begun to switch from conventional power sources to pulsed inverter power sources for their welding operations   The pulsed inverter power source is currently being touted in product literature as capable of generating less fume during the welding process, thereby reducing the need for ventilation Research has shown that under laboratory conditions gas metal arc welding with pulsed arc can reduce fume generation.[1,2] This fume reduction is due to the ability of pulsed current to transfer metal droplets from the wire, through the arc, to the work piece, with minimum heat   The purpose of this study was to evaluate whether the welding fumes generated during pulsed arc welding in the production environment are indeed significantly less than that of conventional arc welding, given similar process parameters

PROCESS DESCRIPTION

Gas metal arc welding (GMAW) is a welding process that uses an arc between a continuous filler metal electrode (wire) and the weld pool   The process is used with shielding from an externally supplied gas and without the application of pressure [3] Conventional GMAW has three distinct modes in which the metal from the wire is transferred to the work piece short circuit, globular, and axial spray [4,5] Short circuit transfer is associated with low average currents and voltage levels and occurs when the wire actually touches the molten weld pool   This creates a short circuit, causing an increase in the current, which subsequently melts the wire tip   Globular transfer occurs at higher voltages and amperages   During this type of transfer, the wire melts before touching the molten pool, and the metal is transferred across the arc through gravity Melted droplets may be up to four times larger than the wire diameter and may be transferred in an irregular pattern   Spray transfer occurs with increasing currents and voltages, using argon-rich shielding gas mixtures   During spray transfer, the magnetic field from the arc surrounds the wire and the high magnetic force from that field pinches the wire down from the end   The resulting molten droplets are smaller than the wire diameter and are transferred across the arc to the work piece in a constricted, axial column   This results in reduced spatter (metal particles expelled during welding, which do not form part of the weld),[6] compared to short circuit and globular transfer modes   However, the temperature of the surface of the molten forming droplet during spray transfer can be in excess of 10,000°F, which is well above the vaporization temperature of steel   It is this high temperature that causes most of the welding fumes during spray transfer

Short circuit transfer has applications in light gauge sheet metal welding   Due to the low heat input of short circuit transfer, use on heavier (thicker) metal can cause non-fusion and is therefore not desirable The concern of non-fusion is reduced during globular transfer because of the increased heat input However the dramatic increase in spatter from this mode of metal transfer prevents it from being a viable production method Axial spray transfer has a high heat input which virtually eliminates the concern of non-fusion Spray transfer also has low spatter and the highest deposition rate of the three modes of metal transfer for conventional GMAW. In general terms, at the survey site, the conventional GMAW process can change from short-circuit, through globular, to axial spray transfer by increasing the arc energy (an increase of voltage and amperage) Because of the above mentioned advantages, most of the conventional GMAW at this site uses the axial spray arc transfer

Pulsed power welding, or pulsed spray transfer, is an arc welding process variation in which the power is cyclically programmed to pulse so that effective but short duration values of power can be utilized Such short duration values are significantly greater than the average value of power [3] When pulsed power welding is used with the GMAW process, small metal droplets are transferred directly through the arc to the work piece The current alternates from a low background current, which begins to melt the wire while maintaining the arc, to a high peak current during which spray transfer occurs One droplet is formed during each high peak current pulse As the wire is advanced, the current pulses again and transfers the next droplet The average arc energy of this pulsed process is significantly lower than during conventional axial spray transfer, thus reducing the amount of welding wire which is vaporized With the reduction of weld wire vaporization, welding fume generation is reduced Some laboratory research indicates that a reduction in welding fume during pulsed arc welding is only attainable for certain ranges of voltages for each wire feed speed [1] If the pulsed technique is to be an effective engineering control, the voltage parameter must be controlled to an optimum setting for the welding operation Voltages that are too low may result in spatter while voltages that are too high will increase the fume generation

PROJECT PARAMETERS

At this site, welding is primarily of low carbon steel using solid wire GMAW conventional and pulsed processes, using a 95% argon/5% oxygen shielding gas During approximately 70% of the welding, 0 045" diameter ER70S-3 wire (Lincoln L50) is used, approximately 20% of the work is completed using 0 035" diameter ER70S-6 wire (Lincoln L56), and 5% using 0 052" diameter ER70S-3 wire (Lincoln L50), with the balance of the welding using other diameters and wire types The two wires, ER70S-3 and ER70S-6, have slightly different additives For 0 035" diameter wire, the manufacturer's suggested current range is 40 amps to 225 amps, and the suggested voltage range is 15 volts to 24 volts [6] For 0 045" diameter wire, a suggested current range of 100 amps to 325 amps is given, and 17 volts to 35 volts is the suggested voltage range, for 0 052" diameter wire, the current range is 200 amps to 400 amps and the voltage range is 19 volts to 36 volts [6] Welders primarily work in the down hand (flat) position and approximately 95% of the work is fillet welds Fillet welds join two parts that are at approximately right angles to each other, in a lap joint (parts overlap), corner joint, or T-joint [7] The cross section of a fillet weld approximates a triangle The welders at the site used primarily four types of steels in their work 572 Grade 50, 1045, A36, and 1018 The metal was dry pickled and descaled prior to welding Base metal thickness ranged from 1/16" - 2"

Welders in Plants 7, 4, and 1 were included in this study Plant 7 produced rubber tire trenchers and directional boring equipment, Plant 4 produced tree products, and Plant 1 produced contract equipment Figure 1 depicts sampled welder and area sample locations

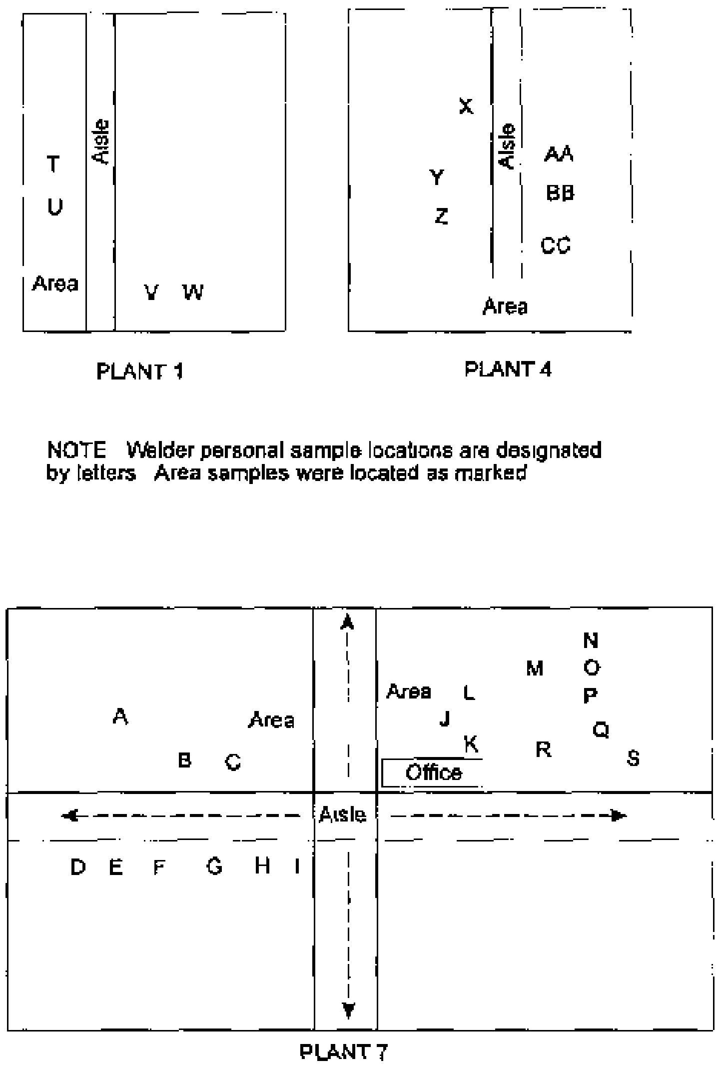

Figure 1 Sampling locations in the three plants evaluated

In Plant 7 each of the sampled welders worked separately at their own workstations In Plant 1, the sampled welders worked in pairs on the same part (Welders T and U, and Welders V and W) In Plant 4, the sampled welders worked separately, except for one pair (Welders Y and Z), who worked on the same part No local exhaust ventilation was used by the welders, however, heated make-up air was provided in the plants Many of the welders used small portable fans in their work areas The plants were under negative pressure Plant sizes were 300' x 450' x 18' for Plant 1 and 320' x 600' x 22' (to a 24' ceiling peak) for Plants 4 and 7 Employees took a 30-minute lunch break at the work site and two 10-minute rest breaks during the 10-hour workday Welders worked a 50-hour work week at the time of the study

The power sources used during the study were the Power Wave™ 450 from the Lincoln Electric Company (Plants 1 and 4) and the Maxtron™ 450 from Miller Electric Manufacturing Company (Plant 7) These power sources can be used for both pulsed spray transfer as well as conventional GMAW Wire feeds ranged from 200 to 600 inches per minute (ipm), amperage levels ranged from 140 to 400 amps, and voltages ranged from 18 to 30 volts Welders in Plant 1 typically used larger diameter wires (0 052"), at a faster rate (600 ipm) than welders in Plants 7 and 4, who typically used 0 045" diameter wire at a rate of 400 ipm During this study, all the welders sampled in Plants 1 and 4 and 60% of welders in Plant 7 used Lincoln L50 wire The remaining 40% of sampled welders in Plant 7 used Lincoln L56 wire

HEALTH HAZARDS AND OCCUPATIONAL EXPOSURE CRITERIA

The effect of welding fumes on an individual's health can vary depending on such factors as the length and intensity of the exposure and the specific toxic metals involved Welding processes involving stainless steel, cadmium- or lead-coated steel, or metals, such as nickel, chrome, zinc, and copper, are particularly hazardous because the fumes produced are considerably more toxic than those encountered from welding low carbon steel NIOSH considers total welding fume and welding fume constituents, such as arsenic, beryllium, cadmium, chromium (VI), and nickel, to be potential occupational carcinogens Welder respiratory ailments can include occupational asthma, siderosis, emphysema, chronic bronchitis, fibrosis of the lung, and lung cancer [8] Other cancers associated with welding include leukemia and cancer of the stomach, brain, nasal sinus, and pancreas A common reaction from overexposure to metal fumes, primarily zinc, is metal fume fever, and symptoms resemble influenza

Welding fumes are a product of the base metal being welded, the welding process and parameters (such as voltage and amperage), the composition of the consumable welding electrode or wire, the shielding gas, and any surface coatings or contaminants on the base metal It has been suggested that as much as 95% of the welding fume actually originates from the melting of the electrode or wire [9] The size of welding fume particulate is highly variable and ranges from less than 1-µm diameter (not visible) to 50-µm diameter (seen as smoke) [10] Some research has shown conventional gas metal arc welding to have a particle size range of 4 µm to 20 µm, and pulsed arc welding to have a range of 0 µm to 4 µm [2]

In general, welding fume constituents may include minerals, such as silica and fluorides, and metals, such as arsenic, beryllium, cadmium, chromium, cobalt, nickel, copper, iron, lead, magnesium, manganese, molybdenum, tin, vanadium, and zinc [8,10,11] Low carbon steel, or mild steel, is distinguished from other steels by a carbon content of less than 0 30% This type of steel consists mainly of iron, carbon, and manganese, but may also contain phosphorus, sulphur, and silicon Most toxic metals, such as nickel and chromium which are present in stainless steel, are not present in low carbon steel However, for completeness, a wide range of welding fume constituents were included in analyses of samples collected during this study

A permissible exposure limit (PEL) for total welding fumes has not been established by OSHA, however, individual PELs have been set for welding fume constituents, and the PEL for total particulates not otherwise regulated is set at 15 mg/m^3 as an 8-hour time-weighted average (TWA) [12] The American Conference of Governmental Industrial Hygienists (ACGIH) has established a threshold limit value (TLV) of 5 mg/m^3 TWA for welding fumes The ACGIH suggests that "conclusions based on total fume concentration are generally adequate if no toxic elements are present in the welding rod, metal, or metal coating and if conditions are not conducive to the formation of toxic gases" [13] The ACGIH also recommends that arc welding fumes be tested frequently to determine whether exposure levels are exceeded for individual constituents [13] NIOSH has concluded that it is not possible to establish an exposure limit for total welding emissions since the composition of welding fumes and gases vary greatly, and the welding constituents may interact to produce adverse health effects. Therefore, NIOSH recommends considering the recommended exposure limits (RELs) for welding fume constituents as upper boundaries of exposure, and implementing recommendations such as good work practices, engineering controls, and medical monitoring to control exposures to these constituents [8]

In addition to the generation of fumes, welding operations can produce toxic gases, such as ozone, carbon monoxide, nitrogen dioxide, and phosgene (formed from chlorinated solvent decomposition) [8, 10, 11] Aside from total welding fume exposures, only ozone exposures were evaluated during this study Ozone results when atmospheric oxygen reacts with the ultraviolet radiation produced by the welding arc Of all the welding processes, GMAW produces some of the highest ozone concentrations [8] Short-term effects from exposure to high concentrations of ozone can include irritation of the mucous membranes and respiratory tract, headaches, and fatigue [8] The OSHA PEL for ozone is 0 1 ppm TWA, while the NIOSH recommended exposure limit (REL) for ozone is 0 1 ppm as a ceiling value The ACGIH TLV for ozone during light work is 0 1 ppm, and 0 05 ppm during heavy work

SAMPLING METHODOLOGY

Data were collected on total welding fume emissions using traditional pumps and filters on the welders, over the 10-hour workday Nineteen welders were sampled in Plant 7, six welders in Plant 4, and four welders in Plant 1 A 37-mm diameter filter cassette, containing a tared, 5-µm pore-size polyvinyl chloride filter, was placed in the breathing zone of the welders, with an attempt to situate the filter high on the welder's lapel, under the welding helmet At lunch time all the personal filters were removed and immediately replaced with new filters During each day, half of the welders in each plant used conventional GMAW, while the other half used pulsed GMAW The selection of which welders used which techniques was randomized On the second day of sampling, the welders switched to the other welding technique On the third day of sampling, the majority of welders returned to the technique they had used during the first day This strategy allowed each welder to be sampled during both pulsed and conventional welding, thus accounting for exposure variations from individual work practices Area samples were also collected in the plants The sampling pumps were calibrated and operated at 2 liters/minute (lpm) Filters were analyzed by DataChem Laboratories according to the NIOSH Method 0500 for total particulate [14] The same filters were subsequently analyzed for elements using the NIOSH Method 7300 [14]

Ozone data were collected in the welders' breathing zones, using passive samplers (Ogawa, Pompano Beach, FL) Because of a limited number of passive samplers (50), data could not be collected on all the welders during all three days of sampling, and no area samples were collected In Plant 7, all nineteen welders were sampled on Day 1 and seven were randomly sampled on Day 2, providing a total of 26 full-shift samples In Plant 1, all four welders were sampled on both Days 1 and 2, resulting in 8 full-shift samples In Plant 4, all six welders were sampled on both Days 1 and 2, resulting in 12 full-shift samples All 50 of the passive samplers, including four blanks, were submitted to the Research Triangle Institute Laboratory to be analyzed by ion chromatography

Video exposure monitoring was used to study in greater detail how specific tasks affected the worker's exposure to air contaminants [15, 16] Real-time data were collected during Days 1 and 2 on one additional welder in Plant 7 who performed several highly repetitive welding operations, using both pulsed and conventional processes On Day 1 the welder assembled 16 figure eight-shaped subassembly parts for gearboxes (eight were completed with conventional GMAW and another eight were completed with pulsed GMAW) On day 2, two gearbox subassemblies were assembled (one was completed with conventional GMAW, the other was completed with a combination of conventional and pulsed GMAW) Welding process parameters during the real-time data collection included a wire feed rate of 375 ipm to 385 ipm, an amperage of 240 to 260, voltages of 26 to 27, and 0 045" diameter ER70S-3 wire

To collect personal real-time exposure data, an aerosol photometer, the Hand-held Aerosol Monitor (HAM) (PPM Inc , Knoxville, TN), was positioned on the welder's chest with a belt and harness A personal pump, operating at 2 lpm was used to draw air through the HAM's sensing chamber A filter cassette was mounted on the HAM to collect the welding fume before it reached the pump This filter cassette was analyzed for total welding fume and elements by the same manner as were the other filter samples After each sampling session of conventional or pulsed welding, the filter on the HAM was replaced The calibration of the HAM varies with aerosol properties, such as refractive index and particle size [15] Therefore, HAM measurements are expressed as relative exposures During the study, the HAM was set at a sensitivity level of 20 mg/m^3 with a one-second averaging time constant Thus, an analog output of one volt equated to a total welding fume concentration of 10 mg/m^3 for a calibration dust The HAM output was recorded by a Metrosonics data logger (Model dl-3200, Metrosonics, Inc , Rochester, NY), and the welder's activities were simultaneously recorded on videotape

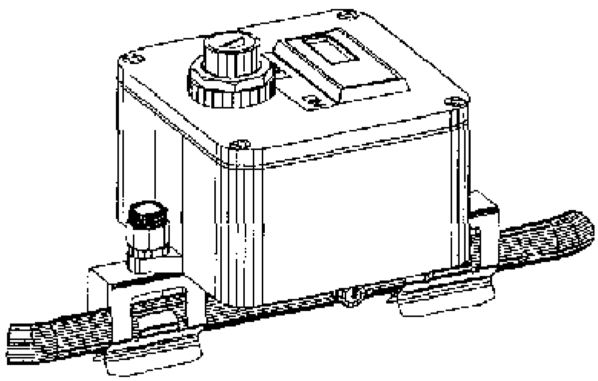

Figure 2 Arc timer used on the Lincoln welding power sources in Plants 1 and 4

Particle count information in the welder's breathing zone was obtained using an optical particle counter (Model 227, Met One, Grants Pass, OR) A 30-cm length of 5-mm inside diameter Tygon® tubing was used to transport the aerosol from the sensor to the instrument The Met One continuously recorded the number of particles counted during a series of consecutive sampling periods During this study, a sampling rate of 2 83 lpm, a sampling period of 10 seconds, and a time between sampling periods of one second were used Particles greater than 0 3 µm and 3 0 µm were counted during each sampling period, and the collected data were downloaded directly to a computer

Air currents in the welding area were assessed with a hot wire anemometer (TSI VelociCalc), which measured air velocities in feet per minute (fpm) Arc timers were used to measure the total amount of time each welder's arc was on during the sampling periods The Miller power sources in Plant 7 already had the capability to measure arc time, however, the Lincoln power sources did not To measure arc times for these welders, a plant technician designed an arc timer that could be clipped to the welding power cable or ground lead (see Figure 2) DC current through the cable magnetized and closed the loop in the mechanism, turning the counter on Arc time was measured in 1/100 of an hour

DATA RESULTS AND ANALYSES

TOTAL WELDING FUME

The total welding fume data collected on the welders personal sample filters and on the area sample filters were all below the OSHA PEL for total particulate A total of 167 personal half-shift samples were collected, 51% were during pulsed GMAW and 49% were during conventional GMAW Twenty-four percent of the personal half-shift samples (40 of 167) were greater than 5 mg/m^3 (Table I) (See Appendix A for concentration and sampling condition data)

Table I Personal Total Welding Fume Data

	Total # Half-Shift Samples			Resulting # Full-Shift Samples		
	Plant 7	Plant 4	Plant 1	Plant 7	Plant 4	Plant 1
Pulsed	53	20	12	26	10	6
Conventional	54	16	12	27	8	6
Total	107	36	24	53	18	12
Pulsed > 5 mg/m^3	4	3	2	1	0	2
Conv > 5 mg/m^3	14	7	10	4	4	4
Total	18	10	12	5	4	6

Of these 40 samples, 31 were collected during conventional welding and 9 were collected during pulsed welding The highest concentration detected was 10 mg/m^3, collected on a conventional welder in Plant 7 When the morning and afternoon filter data were combined to determine the TWA concentration for each welder, 15 of the personal full-shift concentrations were found to be greater than the ACGIH TLV of 5 mg/m^3 for welding fume (Table I) Of these samples, 12 were collected during conventional GMAW and 3 were collected during pulsed GMAW The conventional welder in Plant 7 who had the highest half-shift concentration also had the highest TWA concentration, calculated as 8 mg/m^3

A statistical analysis of the personal half-shift data showed a 24% significant reduction overall in total welding fume levels when using pulsed arc welding versus conventional welding The pulsed technique resulted in personal total welding fume exposure reductions of 21% in Plant 7, 33% in Plant 4, and 25% in Plant 1 (Figure 3)

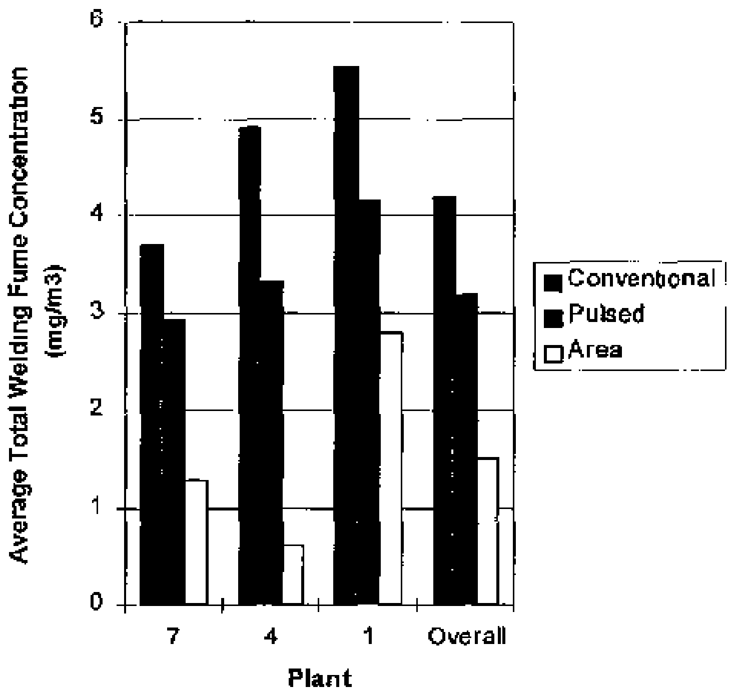

Figure 3 Average total welding fume concentrations as measured by the integrated samplers

No significant interaction was found between welding technique and plant. An evaluation of the overall workers' exposures to total welding fume found that Plant 7 welders were exposed to significantly lower total welding fume levels than welders in Plants 1 and 4 The exposure differences between Plants 1 and 4 were insignificant However, the amount of time the welders actually welded differed significantly among the three plants When comparing arc time to sample time, Plant 7 had the lowest arc time ratio while Plant 1 had the highest Since sampling time was fairly constant in the study, the difference in arc time ratios is considered a direct difference in arc times Thus, the lower fume concentrations on average in Plant 7 can be explained by the lower arc times in that plant (the less welding is performed, the less fume is generated) Statistical analyses showed that the difference between arc times for conventional and pulsed welding was insignificant (Table II) Therefore, the difference in exposures between the two welding techniques cannot be attributed to a difference in their arc times

Table II. Arc Time Data

Plant	Welding Technique	Average Arc Time (min)	% Sample Time Actually Welding
7	Conventional	37	14%
7	Pulsed	45	12%
4	Conventional	51	23%
4	Pulsed	59	22%
1	Conventional	98	38%
1	Pulsed	103	40%
Overall	Conventional	62	25%
Overall	Pulsed	69	25%

WELDING FUME CONSTITUENTS

The elemental analysis of the filter data found no concentrations over the applicable OSHA PELs (See Appendix B for elemental concentration data) Analysis of full-shift manganese exposures for the welders found almost half were greater than the ACGIH TLV for manganese of 0 2 mg/m^3 as a TWA OSHA sets 5 mg/m^3 as a ceiling value for manganese The exposures occurred almost evenly between pulsed and conventional welding operations Manganese concentrations ranged from 0 05 mg/m^3 to 0 60 mg/m^3 The highest personal sample concentration collected, 0 60 mg/m^3, was for a conventional welder in Plant 7 Seventeen of the half-shift personal samples had arsenic concentrations greater than the NIOSH REL of 0 002 mg/m^3 (ceiling value) These exposures were split almost evenly between pulsed and conventional welding operations Arsenic concentrations on the welders ranged from LOD mg/m^3 to 0 01 mg/m^3 The OSHA PEL and ACGIH TLV for arsenic is 0 01 mg/m^3 as a TWA (See Appendix C for the TWA data analysis)

A statistical analysis was performed on several elements (including aluminum, barium, chromium, copper, iron, magnesium, manganese, and zinc) which had measurable quantities for many of the samples Overall, it was shown that Plant 7 had significantly lower exposure levels ($p < 0\ 01$) than Plants 1 and 4, perhaps for the same reason as was stated for the total welding fume data The statistical analysis also found that for these ten elements, exposures generated during conventional GMAW were significantly higher than exposures during pulsed GMAW ($p < 0\ 01$)

OZONE

The average ozone concentration for pulsed arc welders was 40% higher overall than that of the conventional welders (Figure 4) This increase in ozone can be understood because although the average arc energy of pulsed GMAW is lower than that of conventional GMAW, the peak amperage is higher Ultraviolet radiation increases roughly proportional to the square of the current[17] and the rate of formation of ozone depends upon the intensity of the ultraviolet radiation Thus, higher current peaks result in increased ultraviolet radiation which, in turn, increases the amount of ozone generated

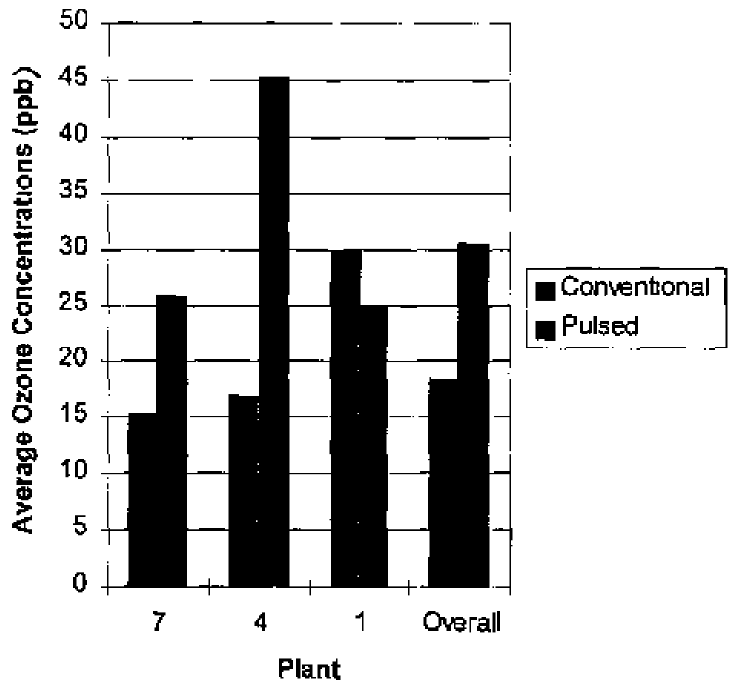

Figure 4 Average ozone concentrations measured on the welders

A statistical analysis of the ozone sampling data did not find the difference between the pulsed and conventional welders to be significant due to the large variation of results Breaking the data down by plant showed a 41% increase in ozone for pulsed arc welders in Plant 7 and a 63% increase for Plant 4 when compared to conventional welders Pulsed arc welders in Plant 1 had a 16% drop in their ozone levels compared to the conventional welders No explanation was found for this result Statistical analyses again did not find any of these differences to be significant ($p < 0.05$) The majority of ozone samplers measured low concentrations, only four of the ozone samplers were above 50 ppb (the TLV during heavy work) Three of these were during pulsed arc welding (out of 24) and one was during conventional welding (out of 22) The highest ozone concentration measured occurred during a pulsed welding operation in Plant 4 (150 ppb) (See Appendix D for ozone concentration data and confidence intervals for the data depicted in Figure 4)

REAL-TIME DATA

The real-time data supported the finding that pulsed arc welders have lower total welding fume levels than conventional welders The aerosol photometer data showed a 13% reduction for one sampling period (Day 1), and a 14% reduction during a second sampling period (Day 2) (Figure 5) A problem occurred during downloading, resulting in a lack of data from a third sampling period (Day 2) Because of the limited amount of real-time data collected, statistically significant differences between conventional and pulsed exposures as measured by the aerosol photometer could not be demonstrated (See Appendix E for the raw aerosol photometer data, presented in graphical format)

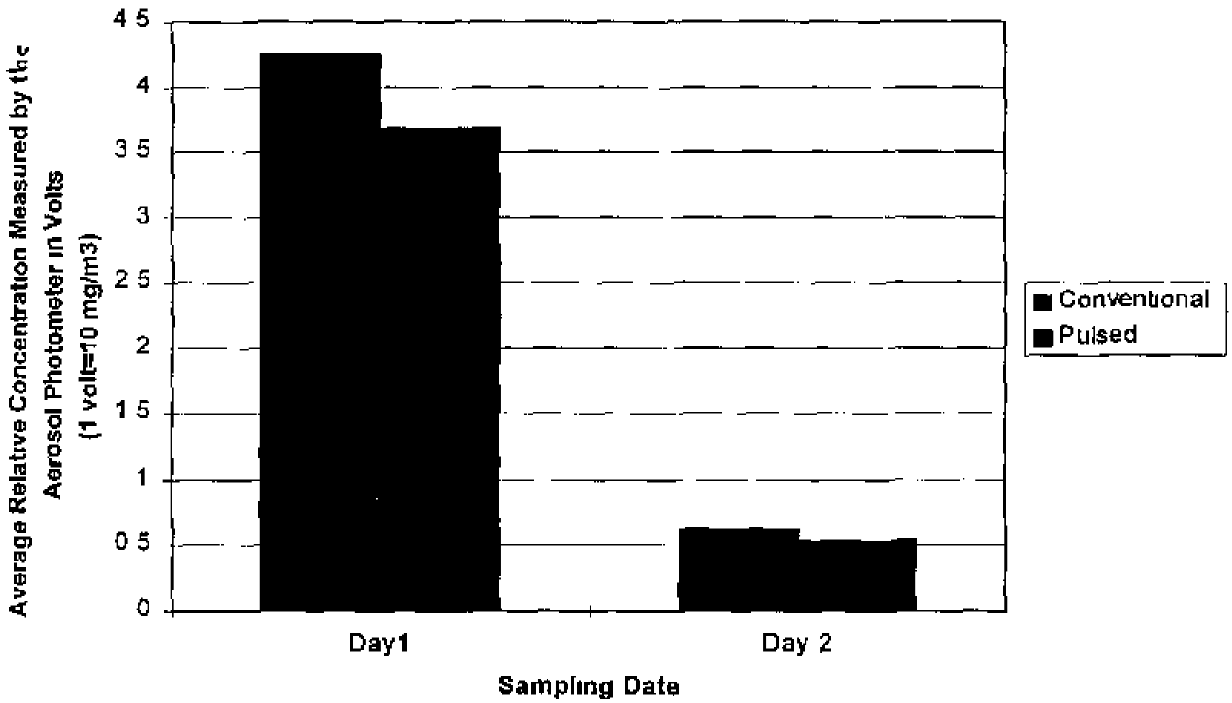

Figure 5 Average relative concentrations as measured by the aerosol photometer during real-time sampling

Filter samples collected on the welder during real-time monitoring also showed a reduction in exposures during the pulsed operation However, the reduction percentages were less than those determined by the aerosol photometer data Instead, the filter data showed only a 5% decrease in total welding fume levels during pulsed arc welding in the first sampling period, and only a 2%

decrease in the second sampling period (Figure 6) This was very limited data as compared to the 167 personal filter samples collected on the other welders throughout the study

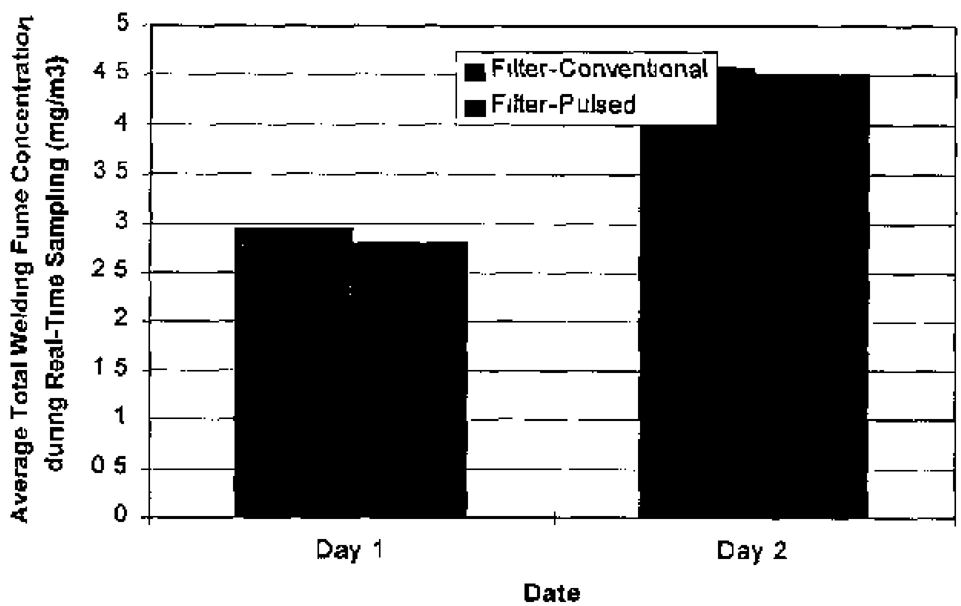

Figure 6 Average total welding fume concentrations as measured by the integrated samplers during real-time sampling

Due to instrument failure, particle count data was only collected during the first sampling period (Table III) The data showed a 3% decrease in particles greater than 0 3 µm during the pulsed technique, however, there was a simultaneous 3% increase in particles greater than 3 0 µm Statistical significance could not be determined because of the limited amount of particle count data collected (See Appendix F for the raw particle count data, presented in tabular and graphical formats)

Table III. Average Particle Counts as Measured with the Met One

Size	Welding Technique	# Sample Periods	Particle Count
>3 0μm	Conventional	65	627
>3 0μm	Pulsed	50	649
>0 3μm	Conventional	65	122,932
>0 3μm	Pulsed	50	119,886

OTHER FACTORS

A regression analysis of the amperage, voltage, humidity, and temperature data established that these factors did not significantly affect the amount of fume generated or the arc time It is possible no effect was found since the parameters were only recorded at one point during the sampling period It is likely that the parameters changed throughout the day, particularly amperages and voltages which may have increased or decreased depending on what the welder was working on Amperage levels were found to be significantly higher in Plant 1 than in Plants 7 and 4, probably due to the use of larger diameter wires at higher wire feed speeds in Plant 1 Temperatures in the three plants ranged from 64°F - 80°F, and humidity levels were around 20% Air velocities in the vicinity of the welders varied, depending on their proximity to man-cooling fans For those welders who had the fans on, the average air velocity at the fan was 1128 fpm, but where the welder actually worked, the average air velocity was only 27 fpm Due to the low air velocities it is unlikely that the fans had much impact on the welders' exposures to fumes In addition, many of the welders frequently moved around their work pieces which would have placed them both upwind and downwind of the welding fumes

CONCLUSIONS

As research under laboratory conditions shows a reduction in welding fume generation from pulsed arc transfer during gas metal arc welding, the results of this research show similar reductions in worker exposures in a production environment Based on the results of this research, the use of pulsed gas metal arc welding in lieu of conventional gas metal arc welding can be an effective engineering control to reduce arc welding fume emissions Because pulsed gas metal arc welding actually reduces the generation of welding fumes at the source rather than just pulling a portion of the fume away from the breathing zone of the welder, it can be considered a more effective engineering control than ventilation controls, such as canopy hoods or fume extraction guns, for reducing welders' fume exposures To ensure optimal fume reduction is achieved, consideration should be given to the correct control of process parameters involved in the pulsed welding operation Optimum control in some cases might be achieved by a combination of pulsed gas metal arc welding and properly designed local exhaust ventilation, particularly if welding fume exposures remain greater than the OSHA PEL or ACGIH TLV, or if significant quantities of ozone are generated during the pulsed arc welding process

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Appendix A Total Welding Fume and Sampling Conditions Data

The NIOSH investigators encountered two problems during sampling and analysis for particulates during the study This portion of the appendix discusses those problems, and how they affected the results of the study

First, due to errors in filter preparation at the contract laboratory, the NIOSH scientists noted that some of the filter cassettes were not properly sealed, that some of the filters were nicked at their edges, and that some of the filters were wrinkled In addition, some of the filters were inadvertently knocked off of the sampling trains and then replaced backwards, causing sampled material to be collected on the back-up pads, and the filters to wrinkle All of these problems may have led to some loss of sampled material Thirty of 207 samples were thus affected (14 percent of the samples) In order to assess the effect these errors may have had on sample results, the mean blank-corrected results for zinc (in micrograms [µg] per filter) from these samples were compared with the mean blank corrected results for zinc recovered from the remaining 177, excluding 18 blanks Zinc was selected because it was identified on all but ten of the air samples and was not found on any of the blanks

The mean amount of zinc recovered from the thirty affected samples was 5 7 µg, with a standard deviation of 4 2. The mean amount of zinc recovered from the remaining 159 samples was 4 9 µg, with a standard deviation of 3 4 There was no significant difference between these two means at the 95% confidence level Thus, these errors in filter preparation and sample collection had no significant effect upon results [1]

Second, a total of 207 filters, including field samples and field blanks were analyzed in seven analytical sets following this survey Sixty filters analyzed for metals in two of seven analytical sets were ashed incorrectly by the contract laboratory The error was discovered after the two sets were digested, the balance of the samples were ashed correctly As a result of the error, recoveries from spiked quality control samples were low, and the field samples were expected to be similarly biased The actual mean recoveries of the eight quality control samples which were incorrectly ashed (along with 95% confidence intervals of the means) were

As 77 4% (74 4 - 80 4%)
Be 67 5% (64 4 - 70 7%)
Cd 78 2% (77 0 - 79 4%)
Ni 66 6% (65 3 - 68 0%)
Pb 58 4% (55 1 - 61 6%)
Zn 76 3% (74 2 - 78 5%)

Thus, for the sixty samples, the reported results for these six elements were multiplied by the inverse of the mean recovery (expressed as a decimal) from the quality control samples, which is given below

As 1 3
Be 1 5
Cd 1 3
Ni 1 5
Pb 1 7
Zn 1 3

The reported results for the remaining 22 elements in the analyses were multiplied by 1 4, the mean of the six coefficients listed above. Finally, when the average blank values were computed for the sample sets, the blanks from these two sample sets were not included in this calculation This was done because the blanks from the remaining five sample sets resulted in similar values, and because a reported result of ND (not detected) could have been any value less than the limit of detection (LOD) For this method, the LOD is determined from prepared solutions, independent of the ashing method. Thus, multiplying the LOD by the coefficient of correction would not have resulted in an accurate estimate of blank values. Instead, all of the blank results from the sample sets were averaged (for each metal) and this average was used as a blank correction value for all of the sample sets For blanks which had reported results of ND, the value of the LOD/√ 2 was used to compute the average [2]

In the following table, data collected for Plant 7 are listed on pages 3-11, while data collected for Plants 1 and 4 are listed on pages 12-17

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Sample #	Location	P/C	Date	Samp T (min)	Rate (lpm)	Vol (m3)	Wt (mg)	Conc (mg/m3)	Start Time	Stop Time
7838	B	p	14-Jan	311	2	0 622	1 47	2 36	6 11 AM	11 24 AM
7894	B	p	14-Jan	211	2	0 422	1 2	2 84	11 24 AM	2 57 PM
7842	J	p	14-Jan	304	2	0 608	2 72	4 47	6 11 AM	11 15 AM
7885	J	p	14-Jan	79	2	0 158	0 57	3 61	11 15 AM	2 47 PM
7839	A	c	14-Jan	307	2	0 614	1 39	2 26	6 12 AM	11 19 AM
7896	A	c	14-Jan	222	2	0 444	2 45	5 52	11 19 AM	3 01 PM
7844	C	c	14-Jan	307 5	2	0 615	3 84	6 24	6 12 AM	11 20 AM
7878	C	c	14-Jan	215 5	2	0 431	4 5	10 44	11 20 AM	2 56 PM
7834	I	c	14-Jan	309 5	2	0 619	0 98	1 58	6 12 AM	11 22 AM
7956	I	c	14-Jan	215 5	2	0 431	1 99	4 62	11 22 AM	2 58 PM
7835	G	p	14-Jan	303 5	2	0 607	3 64	6 00	6 13 AM	11 17 AM
7942	G	p	14-Jan	216 5	2	0 433	2 49	5 75	11 17 AM	2 54 PM
7847	H	c	14-Jan	307	2	0 614	3 9	6 35	6 14 AM	11 21 AM
7893	H	c	14-Jan	214	2	0 428	2 21	5 16	11 21 AM	2 55 PM
7833	F	p	14-Jan	286	2	0 572	2 85	4 98	6 14 AM	11 00 AM
7959	F	p	14-Jan	240	2	0 48	1 68	3 50	11 00 AM	3 00 PM
7855	D	c	14-Jan	290 5	2	0 581	3 06	5 27	6 15 AM	11 05 AM
7958	D	c	14-Jan	232 5	2	0 465	1 3	2 80	11 05 AM	2 57 PM
7856	K	c	14-Jan	285	2	0 57	1 11	1 95	6 15 AM	11 00 AM
7953	K	c	14-Jan	246	2	0 492	1 28	2 60	11 00 AM	3 06 PM
7864	M	p	14-Jan	300	2	0 6	0 26	0 43	6 15 AM	11 15 AM
7877	M	p	14-Jan	207	2	0 414	1 1	2 66	11 15 AM	2 42 PM
7858	N	p	14-Jan	311	2	0 622	2 1	3 38	6 15 AM	11 30 AM
7872	N	p	14-Jan	212	2	0 424	1 58	3 73	11 30 AM	3 06 PM
7850	S	p	14-Jan	312?	2	?	0 41	?	6 16 AM	11 28 AM
7960	S	p	14-Jan	74-178	2	?	2 3	?	11 28 AM	2 26 PM
7837	R	c	14-Jan	311	2	0 622	1 86	2 99	6 16 AM	11 27 AM
7886	R	c	14-Jan	175	2	0 35	1 23	3 51	11 27 AM	2 22 PM
7843	Q	p	14-Jan	288	2	0 576	1 55	2 69	6 16 AM	11 05 AM
7957	Q	p	14-Jan	210	2	0 42	0 94	2 24	11 05 AM	2 36 PM
7827	O	c	14-Jan	292 5	2	0 585	1 56	2 67	6 17 AM	11 10 AM
7949	O	c	14-Jan	208 5	2	0 417	2 11	5 06	11 10 AM	2 39 PM
7857	P	c	14-Jan	131	2	0 262	0 8	3 05	6 17 AM	11 11 AM
7950	P	c	14-Jan	200	2	0 4	1 26	3 15	11 11 AM	2 31 PM
7863	L	p	14-Jan	293 5	2	0 587	1 41	2 40	6 18 AM	11 12 AM
7941	L	p	14-Jan	212 5	2	0 425	3 39	7 98	11 12 AM	2 45 PM
7851	E	p	14-Jan	310 5	2	0 621	0 62	1 00	6 10 AM	11 20 AM
7895	E	p	14-Jan	219 5	2	0 439	0 63	1 44	11 20 AM	2 59 PM
7891	L	c	15-Jan	65-313	2	?	1 45	?	5 45 AM	10 58 AM
7711	L	c	15-Jan	129-241	2	?	0 79	?	10 58 AM	2 59 PM
7948	H	p	15-Jan	292 5	2	0 585	1 55	2 65	5 48 AM	10 40 AM
7654	H	p	15-Jan	261 5	2	0 523	1 54	2 94	10 40 AM	3 01 PM
7865	M	c	15-Jan	306 5	2	0 613	3 6	5 87	5 49 AM	10 56 AM
7704	M	c	15-Jan	294 5	2	0 589	1 32	2 24	10 56 AM	3 51 PM
7866	G	c	15-Jan	289 5	2	0 579	3 37	5 82	5 50 AM	10 40 AM
7702	G	c	15-Jan	257 5	2	0 515	2 94	5 71	10 40 AM	2 58 PM
7829	I	p	15-Jan	287	2	0 574	0 86	1 50	5 51 AM	10 38 AM
7700	I	p	15-Jan	263	2	0 526	1 53	2 91	10 38 AM	3 01 PM
7868	F	c	15-Jan	289	2	0 578	3 35	5 80	5 52 AM	10 41 AM
7716	F	c	15-Jan	259	2	0 518	2 02	3 90	10 41 AM	3 00 PM

Sample #	Location	P/C	Date	Samp T (min)	Rate (lpm)	Vol (m3)	Wt (mg)	Conc (mg/m3)	Start Time	Stop Time
7822	B	c	15-Jan	291 5	2	0 583	1 38	2 37	5 52 AM	10 45 AM
7697	B	c	15-Jan	252 5	2	0 505	1 17	2 32	10 45 AM	2 59 PM
7830	A	p	15-Jan	296	2	0 592	1 31	2 21	5 53 AM	10 49 AM
7709	A	p	15-Jan	246	2	0 492	1	2 03	10 49 AM	2 55 PM
7869	J	c	15-Jan	296	2	0 592	1 35	2 28	5 55 AM	10 51 AM
7696	J	c	15-Jan	298	2	0 596	2 56	4 30	10 51 AM	3 49 PM
7870	E	c	15-Jan	288	2	0 576	2 05	3 56	5 55 AM	10 43 AM
7680	E	c	15-Jan	254	2	0 508	3 14	6 18	10 43 AM	2 57 PM
7954	D	p	15-Jan	285 5	2	0 571	1 16	2 03	5 56 AM	10 42 AM
7717	D	p	15-Jan	256 5	2	0 513	0 69	1 35	10 42 AM	2 59 PM
7902	P	p	15-Jan	309 5	2	0 619	1 35	2 18	5 57 AM	11 06 AM
7710	P	p	15-Jan	283 5	2	0 567	1 45	2 56	11 06 AM	3 49 PM
7879	C	p	15-Jan	288 5	2	0 577	2 53	4 38	5 58 AM	10 46 AM
7703	C	p	15-Jan	250 5	2	0 501	1 67	3 33	10 46 AM	2 56 PM
7951	Q	c	15-Jan	302	2	0 604	2 66	4 40	5 58 AM	11 00 AM
7708	Q	c	15-Jan	292	2	0 584	1 6	2 74	11 00 AM	3 52 PM
7901	O	p	15-Jan	299	2	0 598	1 15	1 92	5 59 AM	10 58 AM
7718	O	p	15-Jan	292	2	0 584	2 31	3 96	10 58 AM	3 50 PM
7828	K	p	15-Jan	221	2	0 442	1 22	2 76	6 00 AM	10 52 AM
7691	K	p	15-Jan	93-285	2	?	0 73	?	10 52 AM	3 37 PM
7910	R	p	15-Jan	300 5	2	0 601	2 25	3 74	6 00 AM	11 01 AM
7706	R	p	15-Jan	220 5	2	0 441	1 37	3 11	11 01 AM	2 42 PM
7900	N	c	15-Jan	294 5	2	0 589	1 08	1 83	6 01 AM	10 56 AM
7719	N	c	15-Jan	228 5	2	0 457	1 93	4 22	10 56 AM	2 45 PM
7899	S	c	15-Jan	297	2	0 594	1 26	2 12	6 01 AM	10 59 AM
7720	S	c	15-Jan	225	2	0 45	1 21	2 69	11 23 AM	3 09 PM
7687	L	c	16-Jan	340 5	2	0 681	1 89	2 78	5 45 AM	11 26 AM
7592	L	c	16-Jan	183 5	2	0 367	1 1	3 00	11 26 AM	2 30 PM
7618	G	c	16-Jan	349	2	0 698	4 06	5 82	5 45 AM	11 36 AM
7649	G	c	16-Jan	189	2	0 378	1 53	4 05	11 36 AM	2 46 PM
7652	H	p	16-Jan	349	2	0 698	2 7	3 87	5 46 AM	11 37 AM
7726	H	p	16-Jan	189	2	0 378	1 53	4 05	11 37 AM	2 46 PM
7714	M	c	16-Jan	333 5	2	0 667	2 67	4 00	5 47 AM	11 21 AM
7586	M	c	16-Jan	179 5	2	0 359	1 53	4 26	11 21 AM	2 21 PM
7670	J	c	16-Jan	339	2	0 678	1 35	1 99	5 47 AM	11 27 AM
7583	J	c	16-Jan	187	2	0 374	0 64	1 71	11 27 AM	2 35 PM
7905	D	p	16-Jan	343	2	0 686	1 11	1 62	5 48 AM	11 32 AM
7725	D	p	16-Jan	191	2	0 382	0 68	1 78	11 32 AM	2 43 PM
7693	A	p	16-Jan	340 5	2	0 681	1 62	2 38	5 49 AM	11 30 AM
7733	A	p	16-Jan	186 5	2	0 373	1 57	4 21	11 30 AM	2 37 PM
7601	F	c	16-Jan	323 5	2	0 647	3 94	6 09	5 49 AM	11 13 AM
7641	F	c	16-Jan	210 5	2	0 421	1 01	2 40	11 13 AM	2 44 PM
7694	E	c	16-Jan	343	2	0 686	0 94	1 37	5 50 AM	11 34 AM
7596	E	c	16-Jan	187	2	0 374	1 13	3 02	11 34 AM	2 41 PM
7678	I	p	16-Jan	348	2	0 696	1 2	1 72	5 50 AM	11 39 AM
7578	I	p	16-Jan	188	2	0 376	0 85	2 26	11 39 AM	2 47 PM
7602	K	p	16-Jan	320	2	0 64	1 75	2 73	5 51 AM	11 11 AM
7581	K	p	16-Jan	202	2	0 404	0 59	1 46	11 11 AM	2 34 PM
7610	P	c	16-Jan	324	2	0 648	1 54	2 38	5 52 AM	11 16 AM
7600	P	c	16-Jan	178	2	0 356	0 67	1 88	11 16 AM	2 15 PM

Sample #	Location	P/C	Date	Samp T (min)	Rate (lpm)	Vol (m3)	Wt (mg)	Conc (mg/m3)	Start Time	Stop Time
7667	R	p	16-Jan	321	2	0 642	3 38	5 26	5 53 AM	11 15 AM
7597	R	p	16-Jan	182	2	0 364	0 74	2 03	11 15 AM	2 16 PM
7662	B	p	16-Jan	337	2	0 674	0 84	1 25	5 53 AM	11 30 AM
7584	B	p	16-Jan	189	2	0 378	0 65	1 72	11 30 AM	2 39 PM
7675	Q	c	16-Jan	321	2	0 642	1 7	2 65	5 54 AM	11 15 AM
7582	Q	c	16-Jan	194	2	0 388	1 64	4 23	11 15 AM	2 29 PM
7604	S	p	16-Jan	348	2	0 696	0 94	1 35	5 54 AM	11 42 AM
7574	S	p	16-Jan	156	2	0 312	0 44	1 41	11 42 AM	2 18 PM
7603	N	c	16-Jan	329 5	2	0 659	1 66	2 52	5 55 AM	11 24 AM
7587	N	c	16-Jan	183 5	2	0 367	0 55	1 50	11 24 AM	2 27 PM
7594	O	p	16-Jan	321	2	0 642	1 02	1 59	5 55 AM	11 16 AM
7593	O	p	16-Jan	187	2	0 374	1 46	3 90	11 16 AM	2 24 PM
7655	RT	p	15-Jan	41	2	0 082	0 23	2 80	1 29 PM	?
7705	RT	c	15-Jan	39	2	0 078	0 23	2 95	2 36 PM	3 15 PM
7666	RT	p	15-Jan	21	2	0 042	0 2	4 76	9 30 AM	9 52 AM
7664	RT	c	15-Jan	12	2	0 024	0 11	4 58	10 36 AM	10 48 AM
7595	RT	p	15-Jan	10	2	0 02	0 09	4 50	10 48 AM	10 58 AM
7849	Area	na	14-Jan	289 5	2	0 579	0 66	1 14	6 44 AM	11 34 AM
7946	Area	na	14-Jan	239 5	2	0 479	0 88	1 84	11 34 AM	3 34 PM
7897	Area	na	15-Jan	277	2	0 554	0 74	1 34	6 10 AM	10 47 AM
7701	Area	na	15-Jan	1155	2	2 31	2 32	1 00	10 47 AM	6 02 AM
7681	Area	na	16-Jan	339 5	2	0 679	0 78	1 15	6 05 AM	11 45 AM
7566	Area	na	16-Jan	190 5	2	0 381	0 49	1 29	11 45 AM	2 56 PM
7824	blank	na	14-Jan	0	0	0	ND			
7821	blank	na	14-Jan	0	0	0	ND			
7692	blank	na	15-Jan	0	0	0	ND			
7686	blank	na	15-Jan	0	0	0	ND			
7657	blank	na	15-Jan	0	0	0	0 02			
7642	blank	na	16-Jan	0	0	0	ND			
7736	blank	na	16-Jan	0	0	0	ND			
7712	blank	na	16-Jan	0	0	0	ND			

Sample #	Time (h:m:s)	Arc T (min)	WireFeed (ipm)	Amps	Volts	Vel @ fan (fpm)	Vel @ wldr (fpm)	Hand	Filter loc?
7838	5 13 00	30 6	287	200	25	1100	70	R	L
7894	3 33 00		287	200	25	1100	70	R	
7842	5 04 00	44 4	197	140	19	1600	50	R	L
7885	3 32 00		197	140	19	1600	50	R	L
7839	5 07 00	49 8	341	245	25	1100	20	R	L
7896	3 42 00		341	245	25	1100	20	R	L
7844	5 08 00	63	300	225	25	FAN OFF	15	R	L
7878	3 36 00		300	225	25	FAN OFF	15	R	L
7834	5 10 00	75	375	295	28	1200	25	R	L
7956	3 36 00		375	295	28	1200	25	R	L
7835	5 04 00	94 8	380	265	27	FAN OFF	30	R	L
7942	3 37 00		380	265	27	FAN OFF	30	R	L
7847	5 07 00	79 8	355	265	26	1200	20	R	R
7893	3 34 00		355	265	26	1200	20	R	R
7833	4 46 00	98	365	235	26	1100	25	R	L
7959	4 00 00		365	235	26	1100	25	R	L
7855	4 50 00	48	325	?	?	fan other way	40	R	L
7958	3 52 00		325	?	?	fan other way	40	R	L
7856	4 45 00	25 8	376	260	26	?	?	R	R
7953	4 06 00		376	260	26	?	?	R	R
7864	5 00 00	126 6	200	145	18	fan off	35	R	?
7877	3 27 00		200	145	18	fan off	35	R	?
7858	5 15 00	90	425	240	28	fan off	20	R	?
7872	3 36 00		425	240	28	fan off	20	R	?
7850	5 12 00	35 4	350	250	25	fan off	30	R	R
7960	2 58 00		350	250	25	fan off	30	R	R
7837	5 11 00	137 4	353	275	27 5	1700	15	both	R
7886	2 55 00		353	275	27 5	1700	15	both	R
7843	4 49 00	87 6	400	240	28	1700	20	L	L
7957	3 31 00		400	240	28	1700	20	L	L
7827	4 53 00	58 8	355	265	25	fan straight up	25-30	R	R
7949	3 29 00		355	265	25	fan straight up	25-30	R	R
7857	4 54 00	83 4	383	26	290	1500	15	R	L
7950	3 20 00		383	26	290	1500	15	R	L
7863	4 54 00	49 8	315	220	24	1150	50	R	?
7941	3 33 00		315	220	24	1150	50	R	?
7851	5 10 00	55 2	325	235	26	1200	50	R	L
7895	3 39 00		325	235	26	1200	50	R	L
7891	5 13 00	13 8	382	220	25	1000	30	?	R
7711	4 01 00	5 4	382	220	25	1000	30	?	R
7948	4 52 00	31 2	385	280	28	1150	20	R	R
7654	4 21 00	45	385	280	28	1150	20	R	R
7865	5 07 00	55 8	385	250	26	1000	27	?	MID
7704	4 55 00	9 6	385	250	26	1000	27	?	MID
7866	4 50 00	36 6	290	?	24 5	no fan	20	?	MID
7702	4 18 00	43 2	290	?	24 5	no fan	20	?	MID
7829	4 47 00	102 6	370	260	25	1100	15	?	MID
7700	4 23 00	59 4	370	260	25	1100	15	?	MID
7868	4 49 00	44 4	360	180	27	no fan	15	?	R
7716	4 19 00	75 6	360	180	27	no fan	15	?	R

Sample #	Time (h:m s)	Arc T (min)	WireFeed (ipm)	Amps	Volts	Vel @ fan (fpm)	Vel @ wldr (fpm)	Hand	Filter loc?
7822	4 53 00	17 4	265	220	23	800	20	?	L
7697	4 14 00	18	265	220	23	800	20	?	L
7830	4 56 00	20 4	350	218	24 7	800	21	?	L
7709	4 06 00	54 6	350	218	24 7	800	21	?	L
7869	4 56 00	9 6	275	?	19	1200	25	?	L
7696	4 58 00	28 8	275	?	19	1200	25	?	L
7870	4 48 00	30	368	270	27	no fan	17	?	L
7680	4 14 00	6	368	270	27	no fan	17	?	L
7954	4 46 00	37 8	350	?	70 (trim?)	fan other direction	8	?	L
7717	4 17 00	21 6	350	?	70 (trim?)	fan other direction	8	?	L
7902	5 09 00	39	395	295	26 9	no fan	25	?	R
7710	4 43 00	51	395	295	26 9	no fan	25	?	R
7879	4 48 00	67 8	291	215	26 5	1100	80	?	L
7703	4 10 00	27	291	215	26 5	1100	80	?	L
7951	5 02 00	48	381	?	?	1250	30	?	L
7708	4 52 00	51	381	?	?	1250	30	?	L
7901	4 59 00	12 6	370	230	26 5	fan blowing up	30	?	L
7718	4 52 00	50 4	370	230	26 5	fan blowing up	30	?	L
7828	4 52 00	79 2	400	250	26	700	70	?	L
7691	4 45 00	56 4	400	250	26	700	70	?	L
7910	5 01 00	80 4	390	250	26 5	1250	18	?	?
7706	3 41 00	60 6	390	250	26 5	1250	18	?	?
7900	4 55 00	44 4	425	270	28 6	1350	30	?	L
7719	3 49 00	34 2	425	270	28 6	1350	30	?	L
7899	4 58 00	17 4	302	240	22 5	800	30	?	L
7720	3 46 00	15	302	240	22 5	800	30	?	L
7687	5 41 00	10 2	224	?	?	1200	30	?	R
7592	3 04 00	8 4	224	?	?	1200	30	?	R
7618	5 51 00	24 6	360	?	24 7	?	19	?	L
7649	3 10 00	17 4	360	?	24 7	?	19	?	L
7652	5 51 00	40 2	355	?	?	?	15	?	L
7726	3 09 00	25 8	355	?	?	?	15	?	L
7714	5 34 00	42	350	270	26 5	?	18	?	MID
7586	3 00 00	13 8	350	270	26 5	?	18	?	MID
7670	5 40 00	9	275	?	19	800	30	?	L
7583	3 08 00	10 2	275	?	19	800	30	?	L
7905	5 44 00	18 6	350	220	25	?	18	?	L
7725	3 11 00	38 4	350	220	25	?	18	?	L
7693	5 41 00	67 8	?	?	?	?	17	?	?
7733	3 07 00	20 4	?	?	?	?	17	?	?
7601	5 24 00	37 2	?	?	?	900	18	?	R
7641	3 31 00	25 2	?	?	?	900	18	?	R
7694	5 44 00	2 4	?	?	?	?	18	?	?
7596	3 07 00	34 8	?	?	?	?	18	?	?
7678	5 49 00	29 4	?	?	?	800	20	?	L
7578	3 08 00	19 8	?	?	?	800	20	?	L
7602	5 20 00	25 2	?	?	?	?	28	?	L
7581	3 23 00	11 4	?	?	?	?	28	?	L
7610	5 24 00	55 2	387	?	25 7	?	19	?	R
7600	2 59 00	59 4	387	?	25 7	?	19	?	R

Sample #	Time (h.m·s)	Arc T (min)	WireFeed (ipm)	Amps	Volts	Vel @ fan (fpm)	Vel @ wldr (fpm)	Hand	Filter loc?
7667	5 22 00	66 6	405	?	?	?	28	?	L
7597	3 01 00	1 8	405	?	?	?	28	?	L
7662	5 37 00	20 4	?	?	?	1180	200(?)	?	L
7584	3 09 00	8 4	?	?	?	1180	200(?)	?	L
7675	5 21 00	54	?	?	?	1200	18	?	L
7582	3 14 00	41 4	?	?	?	1200	18	?	L
7604	5 48 00	14 4	420	?	?	650	20	?	L
7574	2 36 00	1 8	420	?	?	650	20	?	L
7603	5 28 00	19 2	430	?	27 5	?	18	?	L
7587	3 03 00	4 8	430	?	27 5	?	18	?	L
7594	5 21 00	7 2	400	?	?	?	120(?)	?	L
7593	3 08 00	27 6	400	?	?	?	120(?)	?	L
7655	0 41 00	30 6	385	255	26 5	no fan	17		
7705	0 39 00	26 4	385	260	26 4	no fan			
7666	0 21 00	13 8	385	240	27	no fan	30		
7664	0 12 00	7 2	375	250	27	no fan			
7595	0 10 00	6 6	385	235	27	no fan			
7849	4 50 00	na	na	na	na	na	na	na	na
7946	4 00 00	na	na	na	na	na	na	na	na
7897	4 37 00	na	na	na	na	na	na	na	na
7701	19 15 00	na	na	na	na	na	na	na	na
7681	5 40 00	na	na	na	na	na	na	na	na
7566	3 11 00	na	na	na	na	na	na	na	na

Sample #	Humid	Temp (F)	Grind?	Antispatter?	Part Welded	Comments
7838	?	?	Y	?	mainframe	
7894	?	?		?		
7842	?	73	N	N	small handle	
7885	?	73	N	N	small handle	
7839	?	71 5	Y	N	M series	
7896	?	71 5	Y	N	M Series	
7844	?	?	N	Y	Park Brake	Sat on stool (tall guy)
7878	?	?	N	Y	Park brake	Sat on stool (tall guy)
7834	?	72 2	N	N	mainframe	upright, sltly bent
7958	?	72 2	N	N	mainframe	upright, sltly bent
7835	?	72 5	Y	N	boom	standing
7942	?	72 5	Y	N	boom	standing
7847	?	73 3	Y	Y (not much)	backhoe bucket	sitting
7893	?	73 3	Y	Y (not much)	backhoe bucket	sitting
7833	?	72 3	Y	Y	5' Blade	stand slightly bent
7959	?	72 3	Y	Y	5' Blade	stand slightly bent
7855	?	72	N	N	boom head	
7958	?	72	N	N	boom head	
7856	?	72 8	N	Y	10 " bracket	stood-sltly bent - tall, face out of frame
7953	?	72 8	N	Y	10 " bracket	
7864	?	70 7	N	Y	gear box	standing - bent at waist
7877	?	70 7	N	Y	gear box	standing - bent at waist
7858	?	69 5	N	Y	rod box - 10' long	
7872	?	69 5	N	Y	rod box - 10' long	
7850	?	71 5	N	Y	wrapper-radiator shroud	discard 7850 & 7960 in analysis
7960	?	71 5	N	Y	wrapper-radiator shroud	
7837	?	70 8	N	Y	long bead part (3')	standing, slightly bent
7886	?	70 8	N	Y	long bead part (3')	standing, slightly bent
7843	?	69	N	Y	5' undercarriage	
7957	?	69	N	Y	5' undercarriage	
7827	?	71 5	Y	Y	15' rack	standing, didn't weld much
7949	?	71 5	Y	Y	15' rack	standing, didn't weld much
7857	?	69 5	Y	Y	10' lrg rect part in jig	
7950	?	69 5	Y	Y	10' lrg rect part in jig	
7863	?	71	N	Y	operation station	
7941	?	71	N	Y	operation station	
7851	?	71 8	N	N	boom head	welder standing
7895	?	71 8	N	N	boom head	welder standing
7891	?	76 1	Y	N	battery box	discard 7891 & 7711 in analysis
7711	?	76 1	Y	N	battery box	
7948	?	79 5	N	N	main boon	
7654	?	79 5	N	N	main boon	
7865	?	75 9	N	N	subweld for rack	
7704	?	75 9	N	N	subweld for rack	
7866	?	79 3	Y	N	shoes	
7702	?	79 3	Y	N	shoes	
7829	?	75 8	N	N	swing yoke	
7700	?	75 8	N	N	swing yoke	
7868	?	81 2	Y	N	arches	
7716	?	81 2	Y	N	arches	

Sample #	Humid	Temp (F)	Grind?	Antispatter?	Part Welded	Comments
7822	?	78 8	N	N	frame	
7697	?	79 8	N	N	frame	
7830	?	77 2	N	N	slip clutch, shield mount	
7709	?	77 2	N	N	slip clutch, shield mount	
7869	?	78 8	N	N	bar - safety	
7696	?	78 8	N	N	bar - safety	
7870	?	77 7	N	N	boom head	
7680	?	77 7	N	N	boom head	
7954	?	80 5	N	N	frame	
7717	?	80 5	N	N	frame	
7902	?	75	N	N	2440(67)	
7710	?	75	N	N	2440(67)	
7879	?	80 5	N	N	boom mount	
7703	?	80 5	N	N	boom mount	
7951	?	74 6	N	N	under carriage	
7708	?	74 6	N	N	under carriage	
7901	?	75	N	N	rack	
7718	?	75	N	N	rack	
7828	?	78 8	N	N	anchors	
7691	?	78 8	N	N	anchors	discard 7691 in analysis
7910	?	77 7	N	N	EZ4A	
7706	?	77 7	N	N	EZ4A	
7900	?	72 9	N	N	rod boxes	
7719	?	72 9	N	N	rod boxes	
7899	?	75 5	N	N	spring alignment cap	
7720	?	75 5	N	N	spring alignment cap	
7687	?	78 6	N	N	?	
7592	?	78 6	N	N	?	
7618	?	78 5	N	N	?	
7649	?	78 5	N	N	?	
7652	?	78 5	N	N	?	
7726	?	78 5	N	N	?	
7714	?	78 8	N	N	?	
7586	?	78 8	N	N	?	
7670	?	77 5	N	N	?	
7583	?	77 5	N	N	?	
7905	?	77	N	N	?	
7725	?	77	N	N	?	
7693	?	73 9	N	N	?	
7733	?	73 9	N	N	?	
7601	?	77 7	N	N	?	
7641	?	77 7	N	N	?	
7694	?	75 4	N	N	setup mostly	
7596	?	75 4	N	N	setup mostly	
7678	?	75 4	N	N	?	
7578	?	75 4	N	N	?	
7602	?	76 1	N	N	?	
7581	?	76 1	N	N	?	
7610	?	77 7	N	N	?	
7600	?	77 7	N	N	?	

Sample #	Humid	Temp (F)	Grind?	Antispatter?	Part Welded	Comments
7667	?	77 3	N	N	tacking	
7597	?	77 3	N	N	tacking	
7662	?	75 3	N	N	?	
7584	?	75 3	N	N	?	
7675	?	78 8	N	N	?	
7582	?	78 8	N	N	?	
7604	?	77	N	N	?	
7574	?	77	N	N	?	
7603	?	76 7	N	N	?	
7587	?	76 7	N	N	?	
7594	?	77 8	N	N	?	nearby fan blowing
7593	?	77 8	N	N	?	
7655		76	N	N	figure 8 subassembly	
7705			N	N	figure 8 subassembly	
7666		77 2	N	N	gear box	
7664			N	N		
7595			N	N		

Sample #	Plant	Location	P/C	Date	Samp T (min)	Rate (lpm)	Vol (m3)	Wt (mg)	Adj Wt (mg)	Adj Conc (mg/m3)	Start T	Stop T	Time (h m s)
7860	1	W	C	1/14/97	261	2	0 52	2 3	2.32	4 43	6 05 AM	10 26 AM	4 21 00
7861	1	W	C	1/14/97	257	2	0 51	0 8	0 78	1 51	10 26 AM	2 43 PM	4 17 00
7840	1	U	C	1/14/97	197	2	0 39	3 4	3 40	8 62	6 16 AM	9 33 AM	3 17 00
7826	1	U	C	1/14/97	306	2	0 61	3 5	3 50	5 71	9 33 AM	2 39 PM	5 06 00
7845	4	BB	C	1/14/97	247	2	0 49	2 9	2 87	5 80	6 42 AM	10 49 AM	4 07 00
7880	4	BB	C	1/14/97	280	2	0 56	2 6	2 57	4 58	10 49 AM	3 29 PM	4 40 00
7854	4	Y	C	1/14/97	242	2	0 48	2 8	2 74	5 65	6 51 AM	10 53 AM	4 02 00
7884	4	Y	C	1/14/97	269	2	0 54	3 8	3 82	7 09	10 49 AM	3 18 PM	4 29 00
7832	4	X	C	1/14/97	256	2	0 51	2	1 93	3 76	6 47 AM	11 03 AM	4 16 00
7945	4	X	C	1/14/97	262	2	0 52	1 2	1 15	2 19	11 03 AM	3 25 PM	4 22 00
7943	1	V	C	1/15/97	243	2	0 49	2 6	2 53	5 20	6 07 AM	10 10 AM	4 03 00
7825	1	V	C	1/15/97	294	2	0 59	3 5	3 49	5 93	10 10 AM	3 04 PM	4 54 00
7955	1	T	C	1/15/97	243	2	0 49	2 1	2 10	4 31	6 15 AM	10 18 AM	4 03 00
7695	1	T	C	1/15/97	298	2	0 6	2 1	2 13	3 57	10 18 AM	3 16 PM	4 58 00
7874	4	AA	C	1/15/97	285	2	0 57	2 4	2 41	4 22	6 50 AM	11 35 AM	4 45 00
7890	4	AA	C	1/15/97	174	2	0 35	3 2	3 15	9 04	11 35 AM	2 29 PM	2 54 00
7911	4	CC	C	1/15/97	255	2	0 51	2 2	2 23	4 36	6 58 AM	11 13 AM	4 15 00
7684	4	CC	C	1/15/97	199	2	0 4	0 9	0 84	2 10	11 13 AM	2 32 PM	3 19 00
7871	4	Z	C	1/15/97	256	2	0 51	2 8	2 79	5 44	6 54 AM	11 10 AM	4 16 00
7823	4	Z	C	1/15/97	217	2	0 43	2	2 02	4 64	11 10 AM	2 47 PM	3 37 00
7836	1	V	C	1/16/97	244	2	0 49	3 2	3 19	6 53	5 56 AM	10 00 AM	4 04 00
7591	1	V	C	1/16/97	267	2	0 53	3 7	3 68	6 88	10 00 AM	2 27 PM	4 27 00
7677	1	W	C	1/16/97	243	2	0 49	3 5	3 45	7 09	5 59 AM	10 02 AM	4 03 00
7599	1	W	C	1/16/97	269	2	0 54	3 6	3 61	6 70	10 02 AM	2 31 PM	4 29 00
7713	4	BB	C	1/16/97	254	2	0 51	3 5	3 45	6 78	6 29 AM	10 43 AM	4 14 00
7671	4	BB	C	1/16/97	256	2	0 51	1 4	1 43	2 78	10 43 AM	2 59 PM	4 16 00
7699	4	Z	C	1/16/97	252	2	0 5	2 3	2 33	4 61	6 40 AM	10 52 AM	4 12 00
7605	4	Z	C	1/16/97	264	2	0 53	2 8	2 82	5 33	10 52 AM	3 16 PM	4 24 00
7841	1	V	P	1/14/97	266	2	0 53	3 2	3 14	5 89	5 58 AM	10 24 AM	4 26 00
7888	1	V	P	1/14/97	259	2	0 52	3	2 94	5 67	10 24 AM	2 43 PM	4 19 00
7848	1	T	P	1/14/97	259	2	0 52	1 5	1 44	2 77	6 11 AM	10 30 AM	4 19 00
7944	1	T	P	1/14/97	233	2	0 47	1 2	1 22	2 61	10 30 AM	2 23 PM	3 53 00
7853	4	AA	P	1/14/97	104	2	0 21	1 7	1 70	8 15	9 21 AM	11 05 AM	1 44 00
7876	4	AA	P	1/14/97	263	2	0 53	1 4	1 35	2 56	11 05 AM	3 28 PM	4 23 00
7831	4	CC	P	1/14/97	256	2	0 51	0 8	0 81	1 57	6 53 AM	11 09 AM	4 16 00
7883	4	CC	P	1/14/97	261	2	0 52	1 1	1 06	2 02	11 09 AM	3 30 PM	4 21 00
7846	4	Z	P	1/14/97	243	2	0 49	1 7	1 69	3 47	6 51 AM	10 54 AM	4 03 00
7947	4	Z	P	1/14/97	264	2	0 53	1 8	1 74	3 29	10 54 AM	3 18 PM	4 24 00
7873	1	W	P	1/15/97	228	2	0 46	1	1 00	2 18	6 26 AM	10 14 AM	3 48 00
7683	1	W	P	1/15/97	294	2	0 59	2 6	2 53	4 29	10 14 AM	3 08 PM	4 54 00
7867	1	U	P	1/15/97	240	2	0 48	3 4	3 41	7 09	6 21 AM	10 21 AM	4 00 00
7681	1	U	P	1/15/97	293	2	0 59	1 9	1 85	3 15	10 21 AM	3 14 PM	4 53 00
7887	4	BB	P	1/15/97	261	2	0 52	1 6	1 54	2 94	6 46 AM	11 07 AM	4 21 00
7658	4	BB	P	1/15/97	214	2	0 43	1 2	1 17	2 72	11 07 AM	2 41 PM	3 34 00
7875	4	X	P	1/15/97	257	2	0 51	0 7	0 73	1 41	6 41 AM	10 58 AM	4 17 00
7685	4	X	P	1/15/97	219	2	0 44	0 6	0 57	1 29	10 58 AM	2 37 PM	3 39 00
7882	4	Y	P	1/15/97	254	2	0 51	1 9	1 93	3 79	7 02 AM	11 16 AM	4 14 00
7889	4	Y	P	1/15/97	215	2	0 43	1 6	1 55	3 59	11 16 AM	2 51 PM	3 35 00
7688	1	U	P	1/16/97	240	2	0 48	3 1	3 06	6 36	6 09 AM	10 09 AM	4 00 00

Sample #	Plant	Location	P/C	Date	Samp T (min)	Rate (lpm)	Vol (m3)	Wt (mg)	Adj Wt (mg)	Adj Conc (mg/m3)	Start T	Stop T	Time (h m s)
7606	1	U	P	1/16/97	270	2	0 54	2 7	2 68	4 95	10 09 AM	12 39 PM	2 30 00
7669	1	T	P	1/16/97	244	2	0 49	1 2	1 22	2 49	6 07 AM	10 11 AM	4 04 00
7590	1	T	P	1/16/97	269	2	0 54	1 4	1 38	2 56	10 11 AM	2 40 PM	4 29 00
7692	4	CC	P	1/16/97	253	2	0 51	3 3	3 29	6 49	6 25 AM	10 38 AM	4 13 00
7663	4	CC	P	1/16/97	258	2	0 52	0 9	0 86	1 66	10 38 AM	2 56 PM	4 18 00
7715	4	AA	P	1/16/97	253	2	0 51	3	2 97	5 86	6 34 AM	10 47 AM	4 13 00
7672	4	AA	P	1/16/97	258	2	0 52	2 1	2 05	3 96	10 47 AM	3 05 PM	4 18 00
7653	4	Y	P	1/16/97	251	2	0 5	2 3	2 27	4 51	6 43 AM	10 54 AM	4 11 00
7608	4	Y	P	1/16/97	255	2	0 51	2	2 03	3 97	10 54 AM	3 09 PM	4 15 00
7698	4	X	P	1/16/97	254	2	0 51	0 9	0 90	1 76	6 48 AM	11 02 AM	4 14 00
7607	4	X	P	1/16/97	251	2	0 5	0 6	0 56	1 11	11 02 AM	3 13 PM	4 11 00
7652	1	area	na	1/14/97	478	2	0 96	2 4	2 34	2 44	6 21 AM	2 19 PM	7 58 00
7662	4	area	na	1/14/97	484	2	0 97	0 9	0 83	0 85	7 12 AM	3 16 PM	8 04 00
7904	1	area	na	1/15/97	451	2	0 9	2 6	2 53	2 80	7 49 AM	3 20 PM	7 31 00
7903	4	area	na	1/15/97	435	2	0 87	0 3	0 27	0 30	7 30 AM	2 45 PM	7 15 00
7668	1	area	na	1/16/97	552	2	1 1	3 5	3 46	3 13	6 13 AM	3 25 PM	9 12 00
7707	4	area	na	1/16/97	491	2	0 98	0 7	0 69	0 70	6 50 AM	3 01 PM	8 11 00
7907	1	blank	B	1/14/97	0	0	0	ND					
7909	1	blank	B	1/14/97	0	0	0	ND					
7689	1	blank	B	1/15/97	0	0	0	0					
7881	1	blank	B	1/15/97	0	0	0	0	Avg blank weight (1)			0 025	mg
7598	1	blank	B	1/16/97	0	0	0	0					
7589	1	blank	B	1/16/97	0	0	0	0 1					
7665	4	blank	B	1/16/97	0	0	0	0					
7673	4	blank	B	1/16/97	0	0	0	ND	Avg blank weight (4)			0 016	mg
7908	4	blank	B	1/14/97	0	0	0	0					
7912	4	blank	B	1/14/97	0	0	0	ND					

Sample #	Arc T (min)	WireFeed (ipm)	Amps	Volts	Vel nr fan (fpm)	Vel nr. wldr (fpm)	Hand	Filter	Humid	Temp (F)	Grind?	Antispat?
7860	79 2	550/450	385	30 2/26 3	?	?	R	?	22	75	N	N
7861	82 8	550/450	385	30 2/26 3	?	?	R	?	22	75	N	N
7840	81	600	395	30	600	?	both	?	22	77	N	N
7826	134	600	395	30	600	?	both	?	22	77	N	N
7845	70 2	430	303	27 5	?	?	R	?	20	76	N	N
7880	58 2	430	303	27 5	?	?	R	?	20	76	N	N
7854	72	345/486	270	24 6/28 5	?	?	R	?	20	76	N	N
7884	75 6	345/486	270	24 6/28 5	?	?	R	?	20	76	N	N
7832	81 6	400/475	?	26 3/27 6	?	?	R	?	20	76	N	Y
7945	83 4	400/476	?	26 3/27 6	?	?	R	?	20	76	N	Y
7943	78 6	600/450	390	29/27 2	?	?	?	?	?	?	N	N
7825	91 2	600/450	390	29/27 2	?	?	?	?	?	?	N	N
7855	142	600/350	290	29 7/25	?	?	?	?	?	?	N	N
7695	128	600/350	290	29 7/25	?	?	?	?	?	?	N	N
7874	43 8	~485	?	26	?	?	R	?	23	71	N	N
7890	23 4	485	?	26	?	?	R	?	23	71	N	N
7911	54 6	427/350	?	27 8/26	no fan	?	R	?	23	71	N	N
7684	16 2	427/350	?	27 8/26	no fan	?	R	?	23	71	N	N
7871	55 8	475/250	160	28 7/21 7	?	?	R	?	?	71	N	N
7823	49 8	475/250	160	28 7/21 7	?	?	R	?	?	71	N	N
7836	88 2	600/450	?	29/27 2	1500	70	L	L	22	65	N	N
7591	87	600/450	?	29/27 2	1500	70	L	L	22	65	N	N
7677	90 6	450/550	?	26 8/28 6	?	50	R	L	?	?	N	N
7599	91 2	450/550	?	26 8/28 6	?	50	R	L	?	?	N	N
7713	78 6	475	?	30	?	40	R	R	?	?	N	N
7671	47 4	475	?	30	?	40	R	R	?	?	N	N
7699	60 6	475/250	?	28 7/21 7	?	?	R	L	?	?	N	N
7605	66 6	475/250	?	28 7/21 7	?	?	R	L	?	?	N	N
7841	82 8	650/471	400/310	28/21 7	?	?	L	?	22	75	N	N
7888	82 8	650/471	400/310	28/21 7	?	?	L	?	22	75	N	N
7848	106	377	250	23	?	?	?	?	22	77	N	N
7944	118	377	250	23	?	?	?	?	22	77	N	N
7853	59 4	485	250	24	?	?	R	?	20	76	N	N
7876	49 8	485	250	24	?	?	R	?	20	76	N	N
7831	107	427	230	25 6	?	?	R	?	20	76	N	Y
7883	64 2	427	230	25 6	?	?	R	?	20	76	N	Y
7846	16 2	240/485	270	20/24 4	?	?	R	?	20	76	N	N
7947	19 8	240/485	270	20/24 4	?	?	R	?	20	76	N	N
7873	70 8	450/588	?	26 8/28 8	?	?	?	?	24%	63 6	N	N
7683	84	450/588	?	26 8/28 8	?	?	?	?	24%	63 6	N	N
7867	113	700/440	260/400	23 7/32 2	?	?	?	?	23	75 7	N	N
7681	106	700/440	260/400	23 7/32 2	?	?	?	?	23	75 7	N	N
7887	18 6	485	240	23	?	?	R	?	23	71	N	N
7658	11 4	485	240	23	?	?	R	?	23	71	N	N
7875	36 6	500/400	?	27 5/25 7	?	?	R	?	23	71	N	N
7685	28 2	500/400	?	27 5/25 7	?	?	R	?	23	71	N	N
7882	78	485/280	252/215	24 4/20	?	?	?	?	23	71	N	N
7889	75	485/280	252/215	24 4/20	?	?	?	?	23	71	N	N
7688	106	700/447	?	32/24 5	?	52	both	L	?	70 9	N	N

Sample #	Arc T (min)	WireFeed (ipm)	Amps	Volts	Vel nr fan (fpm)	Vel nr wldr (fpm)	Hand	Filter	Humid	Temp (F)	Grind?	Antispat?
7606	104	700/447	?	32/24 5	?	52	both	L	?	70 9	N	N
7669	134	600/360	?	28 5/22 5	?	22	R	L	?	?	N	N
7590	133	600/360	?	28 5/22 5	?	22	R	L	?	?	N	N
7692	55 8	427/350	?	25/23	?	?	R	L	23	68 9	N	Y(?)
7663	9 6	427/350	?	25/23	?	?	R	L	23	68 9	N	Y(?)
7715	49 8	485/350	?	23 8/22	?	41	R	L	?	?	N	L
7672	33	485/350	?	23 8/22	?	41	R	L	?	?	N	L
7653	69 6	485/280	?	24/20 5	?	50	R	L	?	?	N	N
7608	85 8	485/280	?	24/20 5	?	50	R	L	?	?	N	N
7698	91 8	500/400	?	28 5/26 5	?	62	R	R	?	?	N	N
7607	67 2	500/400	?	28 5/26 5	?	62	R	R	?	?	N	N

Sample #	Part Welded	Comments
7860	?	
7861	?	
7840	?	
7826	?	
7845	?	
7830	?	
7854	infeed chute & frame	
7884	for disc chipper	
7832	chipper drum	
7945	chipper drum	
7943	4WD tractor frame	
7825	4WD tractor frame	
7955	rear part of	
7695	+4 Wheel Drive	
7874	?	
7890	- ?—	
7911	feed housing	
7684	+for brush chipper	
7871	frames for 1250 chipper	
7823	frames for 1250 chipper	
7836	4 WD tractor frame	
7591	4 WD tractor frame	
7677	4 WD tractor frame	
7599	4 WD tractor frame	
7713	chipper frame sub-weld	
7671	chipper frame sub-weld	
7699	chipper frame	
7605	chipper frame	
7841	?	
7888	?	
7848	?	only 16' ceiling, lighting, large open build - strong negative pressure in building
7944	?	only 16' ceiling, lighting, large open build - strong negative pressure in building
7853	?	
7876	?	
7831	feed housing	
7883	+for brush chipper	
7846	?	
7947	?	
7873	4WD tractor frame	
7683	4WD tractor frame	
7867	rear part of	
7681	+4 Wheel Drive	
7887	Frames	
7858	Lower chipper housing	
7875	cutter drum	
7685	cutter drum	
7882	frames for 1250 chipper	
7889	frames for 1250 chipper	
7686	rear frame 4 wd tractor	

Sample #	Part Welded	Comments
7606	rear frame 4 wd tractor	
7669	Rear frame 4 wd tractor	
7590	Rear frame 4 wd tractor	
7692	feeder housing for chipper	fans on in PM
7663	feeder housing for chipper	
7715	chipper frame tacking	
7672	chipper frame tacking	
7653	chipper frame	
7608	chipper frame	
7698	cutter drum	
7607	cutter drum	

Appendix B Elemental Sampling Data

(Note Concentration data listed in the following table have been truncated to two decimal places)

					Sample	Rate		Concentrations (mg/m3)		
Sample #	**Plant**	**Location**	**P or C**	**Date**	**Time (min)**	**(lpm)**	**Vol (m3)**	***Aluminum***	***Arsenic***	***Barium***
7839	7	A	C	14-Jan	307	2	0 614	0 01	ND	0 00
7896	7	A	C	14-Jan	222	2	0 444	0 01	0 01	0 02
7845	4	BB	C	14-Jan	247	2	0 494	0 01	ND	0 00
7880	4	BB	C	14-Jan	280	2	0 56	0 01	ND	0 00
7844	7	C	C	14-Jan	307 5	2	0 615	0 01	ND	0 01
7878	7	C	C	14-Jan	215 5	2	0 431	0 01	0 01	0 01
7855	7	D	C	14-Jan	290 5	2	0 581	0 10	0 01	0 01
7958	7	D	C	14-Jan	232 5	2	0 465	0 01	0 01	0 01
7847	7	H	C	14-Jan	307	2	0 614	0 01	0 01	0 01
7893	7	H	C	14-Jan	214	2	0 428	0 01	ND	0 02
7834	7	I	C	14-Jan	309 5	2	0 619	0 01	0 01	0 02
7956	7	I	C	14-Jan	215 5	2	0 431	0 01	0 01	0 02
7953	7	K	C	14-Jan	246	2	0 492	0 01	ND	0 02
7856	7	K	C	14-Jan	285	2	0 57	0 01	0 01	0 01
7827	7	O	C	14-Jan	292 5	2	0 585	0 00	ND	0 01
7949	7	O	C	14-Jan	208 5	2	0 417	0 00	ND	0 02
7857	7	P	C	14-Jan	131	2	0 262	ND	ND	0 00
7950	7	P	C	14-Jan	200	2	0 4	0 00	ND	0 02
7837	7	R	C	14-Jan	311	2	0 622	0 00	ND	0 01
7886	7	R	C	14-Jan	175	2	0 35	0 00	ND	0 01
7840	1	U	C	14-Jan	197	2	0 394	0 02	ND	0 00
7826	1	U	C	14-Jan	306	2	0 612	0 02	ND	0 00
7860	1	W	C	14-Jan	261	2	0 522	0 01	ND	0 00
7861	1	W	C	14-Jan	257	2	0 514	0 01	ND	0 00
7832	4	X	C	14-Jan	256	2	0 512	0 01	ND	0 00
7945	4	X	C	14-Jan	262	2	0 524	0 01	ND	0 00
7854	4	Y	C	14-Jan	242	2	0 484	0 01	ND	0 00
7864	4	Y	C	14-Jan	269	2	0 538	0 02	ND	0 00
7874	4	AA	C	15-Jan	285	2	0 57	0 01	ND	0 00
7890	4	AA	C	15-Jan	174	2	0 348	0 00	ND	0 00
7822	7	B	C	15-Jan	293	2	0 586	0 03	ND	0 01
7697	7	B	C	15-Jan	254	2	0 508	0 01	ND	0 01
7911	4	CC	C	15-Jan	255	2	0 51	0 01	ND	0 00
7684	4	CC	C	15-Jan	199	2	0 398	ND	ND	0 00
7870	7	E	C	15-Jan	288	2	0 576	0 01	ND	0 01
7680	7	E	C	15-Jan	254	2	0 508	0 02	ND	0 01
7868	7	F	C	15-Jan	289	2	0 578	0 02	ND	0 01
7716	7	F	C	15-Jan	259	2	0 518	0 01	ND	0 01
7868	7	G	C	15-Jan	289 5	2	0 579	0 01	ND	0 01
7702	7	G	C	15-Jan	257 5	2	0 515	0 02	ND	0 01
7869	7	J	C	15-Jan	296	2	0 592	0 01	ND	0 01
7696	7	J	C	15-Jan	298	2	0 596	0 02	ND	0 01
7865	7	M	C	15-Jan	306 5	2	0 613	0 01	ND	0 01
7704	7	M	C	15-Jan	294 5	2	0 589	0 01	ND	0 01
7900	7	N	C	15-Jan	294 5	2	0 589	0 01	ND	0 01
7719	7	N	C	15-Jan	228 5	2	0 457	0 02	ND	0 01
7851	7	Q	C	15-Jan	302	2	0 604	0 01	ND	0 02
7708	7	Q	C	15-Jan	292	2	0 584	0 01	ND	0 01
7705	7	RT	C	15-Jan	39	2	0 078	ND	ND	0 00
7664	7	RT	C	15-Jan	12	2	0 024	ND	ND	0 00
7899	7	S	C	15-Jan	297	2	0 594	0 01	ND	0 01
7720	7	S	C	15-Jan	225	2	0 45	0 03	ND	0 01
7955	1	T	C	15-Jan	243	2	0 486	0 01	ND	0 00

					Sample	Rate		Concentrations (mg/m3)		
Sample #	**Plant**	**Location**	**P or C**	**Date**	**Time (min)**	**(lpm)**	**Vol (m3)**	**Aluminum**	**Arsenic**	**Barium**
7695	1	T	C	15-Jan	298	2	0 596	0 02	ND	0 00
7943	1	V	C	15-Jan	243	2	0 486	0 01	ND	0 00
7825	1	V	C	15-Jan	294	2	0 588	0 01	ND	0 00
7871	4	Z	C	15-Jan	256	2	0 512	0 01	ND	0 00
7823	4	Z	C	15-Jan	217	2	0 434	0 02	ND	0 00
7713	4	BB	C	16-Jan	254	2	0 508	0 02	ND	0 00
7671	4	BB	C	16-Jan	256	2	0 512	0 02	ND	0 00
7694	7	E	C	16-Jan	343	2	0 686	0 01	ND	0 00
7596	7	E	C	16-Jan	187	2	0 374	0 02	ND	0 01
7601	7	F	C	16-Jan	323 5	2	0 647	0 01	ND	0 00
7641	7	F	C	16-Jan	210 5	2	0 421	0 02	ND	0 01
7618	7	G	C	16-Jan	349	2	0 698	0 02	ND	0 00
7649	7	G	C	16-Jan	189	2	0 378	0 01	ND	0 01
7670	7	J	C	16-Jan	339	2	0 678	0 01	ND	0 00
7583	7 -	~~J~~	C	16-Jan	187	2	0 374	0 01	ND	0 01
7687	7	L	C	16-Jan	340	2	0 68	0 01	ND	0 00
7592	7	L	C	16-Jan	184	2	0 368	0 01	ND	0 01
7714	7	M	C	16-Jan	333 5	2	0 667	0 01	ND	0 00
7586	7	M	C	16-Jan	179 5	2	0 359	0 01	ND	0 01
7603	7	N	C	16-Jan	329 5	2	0 659	0 00	ND	0 00
7587	7	N	C	16-Jan	183 5	2	0 367	0 01	ND	0 01
7610	7	P	C	16-Jan	324	2	0 648	0 01	ND	0 00
7600	7	P	C	16-Jan	178	2	0 356	0 02	ND	0 01
7675	7	Q	C	16-Jan	321	2	0 642	0 01	ND	0 00
7582	7	Q	C	16-Jan	194	2	0 388	0 01	ND	0 01
7836	1	V	C	16-Jan	244	2	0 488	0 01	ND	0 00
7591	1	V	C	16-Jan	267	2	0 534	0 02	ND	0 00
7677	1	W	C	16-Jan	243	2	0 486	0 02	ND	0 00
7599	1	W	C	16-Jan	269	2	0 538	0 01	ND	0 00
7699	4	Z	C	16-Jan	252	2	0 504	0 02	ND	0 00
7605	4	Z	C	16-Jan	264	2	0 528	0 01	ND	0 00
7853	4	AA	P	14-Jan	104	2	0 208	0 01	ND	0 00
7876	4	AA	P	14-Jan	263	2	0 526	0 01	ND	0 00
7838	7	B	P	14-Jan	311	2	0 622	0 01	0 01	0 01
7894	7	B	P	14-Jan	211	2	0 422	0 01	0 01	0 01
7831	4	CC	P	14-Jan	256	2	0 512	0 01	ND	0 00
7883	4	CC	P	14-Jan	261	2	0 522	0 00	ND	0 00
7851	7	E	P	14-Jan	310 5	2	0 621	ND	ND	0 01
7895	7	E	P	14-Jan	219 5	2	0 439	0 00	ND	0 01
7833	7	F	P	14-Jan	286	2	0 572	0 01	0 01	0 01
7959	7	F	P	14-Jan	240	2	0 48	0 01	0 01	0 01
7835	7	G	P	14-Jan	303 5	2	0 607	0 01	ND	0 01
7942	7	G	P	14-Jan	216 5	2	0 433	0 01	0 01	0 01
7842	7	J	P	14-Jan	304	2	0 608	0 01	0 01	0 01
7885	7	J	P	14-Jan	79	2	0 158	0 01	ND	0 01
7863	7	L	P	14-Jan	293 5	2	0 587	0 00	ND	0 01
7941	7	L	P	14-Jan	212 5	2	0 425	0 01	ND	0 02
7864	7	M	P	14-Jan	300	2	0 6	0 00	ND	0 00
7877	7	M	P	14-Jan	207	2	0 414	0 01	0 01	0 01
7872	7	N	P	14-Jan	212	2	0 432	0 01	ND	0 02
7858	7	N	P	14-Jan	311	2	0 63	0 01	0 01	0 01
7843	7	Q	P	14-Jan	289	2	0 578	0 00	ND	0 01
7957	7	Q	P	14-Jan	211	2	0 422	ND	ND	0 02

Sample #	Plant	Location	P or C	Date	Sample Time (min)	Rate (lpm)	Vol (m3)	Concentrations (mg/m3) Aluminum	Arsenic	Barium
7848	1	T	P	14-Jan	259	2	0 518	0 01	ND	0 00
7944	1	T	P	14-Jan	233	2	0 466	0 01	ND	0 00
7841	1	V	P	14-Jan	266	2	0 532	0 01	ND	0 00
7888	1	V	P	14-Jan	259	2	0 518	0 01	ND	0 00
7846	4	Z	P	14-Jan	243	2	0 486	0 01	ND	0 00
7947	4	Z	P	14-Jan	264	2	0 528	0 01	ND	0 00
7830	7	A	P	15-Jan	296	2	0 592	0 02	ND	0 01
7709	7	A	P	15-Jan	246	2	0 492	0 03	ND	0 01
7687	4	BB	P	15-Jan	261	2	0 522	0 00	ND	0 00
7658	4	BB	P	15-Jan	214	2	0 428	0 00	ND	0 00
7879	7	C	P	15-Jan	288 5	2	0 577	0 01	ND	0 01
7703	7	C	P	15-Jan	250 5	2	0 501	0 01	ND	0 01
7954	7	D	P	15-Jan	285 5	2	0 571	0 02	ND	0 01
7717	7	D	P	15-Jan	256 5	2	0 513	0 02	ND	0 01
7948	7	H	P	15-Jan	292 5	2	0 585	0 00	ND	0 01
7654	7	H	P	15-Jan	261 5	2	0 523	0 01	ND	0 01
7829	7	I	P	15-Jan	287	2	0 574	0 02	ND	0 01
7700	7	I	P	15-Jan	263	2	0 526	0 02	ND	0 01
7828	7	K	P	15-Jan	221	2	0 442	0 01	ND	0 01
7901	7	O	P	15-Jan	299	2	0 598	0 01	ND	0 01
7718	7	O	P	15-Jan	292	2	0 584	0 01	ND	0 01
7902	7	P	P	15-Jan	309 5	2	0 619	0 02	ND	0 01
7710	7	P	P	15-Jan	283 5	2	0 567	0 03	ND	0 01
7910	7	R	P	15-Jan	300 5	2	0 601	0 01	ND	0 01
7706	7	R	P	15-Jan	220 5	2	0 441	0 01	ND	0 01
7655	7	RT	P	15-Jan	41	2	0 082	ND	ND	0 00
7666	7	RT	P	15-Jan	21	2	0 042	ND	ND	ND
7595	7	RT	P	15-Jan	10	2	0 02	ND	ND	0 00
7867	1	U	P	15-Jan	240	2	0 48	0 01	ND	0 00
7681	1	U	P	15-Jan	293	2	0 586	ND	ND	0 00
7873	1	W	P	15-Jan	228	2	0 456	0 01	ND	0 00
7683	1	W	P	15-Jan	294	2	0 588	0 01	ND	0 00
7875	4	X	P	15-Jan	257	2	0 514	0 00	ND	0 00
7685	4	X	P	15-Jan	219	2	0 438	ND	ND	0 00
7882	4	Y	P	15-Jan	254	2	0 508	0 01	ND	0 00
7889	4	Y	P	15-Jan	215	2	0 43	0 01	ND	0 00
7693	7	A	P	16-Jan	340 5	2	0 681	0 02	ND	0 00
7733	7	A	P	16-Jan	186 5	2	0 373	0 02	ND	0 01
7715	4	AA	P	16-Jan	253	2	0 506	0 02	ND	0 00
7672	4	AA	P	16-Jan	258	2	0 516	0 01	ND	0 00
7662	7	B	P	16-Jan	337	2	0 674	0 01	ND	0 00
7584	7	B	P	16-Jan	189	2	0 378	0 01	ND	0 01
7692	4	CC	P	16-Jan	253	2	0 506	0 02	ND	0 00
7663	4	CC	P	16-Jan	258	2	0 516	0 01	ND	0 00
7905	7	D	P	16-Jan	343	2	0 686	0 01	ND	0 00
7725	7	D	P	16-Jan	191	2	0 382	0 02	ND	0 01
7652	7	H	P	16-Jan	349	2	0 698	0 01	ND	0 00
7726	7	H	P	16-Jan	189	2	0 378	0 02	ND	0 01
7678	7	I	P	16-Jan	348	2	0 696	0 01	ND	0 00
7578	7	I	P	16-Jan	188	2	0 376	0 02	ND	0 02
7602	7	K	P	16-Jan	320	2	0 64	0 01	ND	0 00
7581	7	K	P	16-Jan	202	2	0 404	0 01	ND	0 01
7594	7	O	P	16-Jan	321	2	0 642	0 00	ND	0 00

					Sample	Rate		Concentrations (mg/m3)		
Sample #	Plant	Location	P or C	Date	Time (min)	(lpm)	Vol (m3)	Aluminum	Arsenic	Barium
7848	1	T	P	14-Jan	259	2	0 518	0 01	ND	0 00
7944	1	T	P	14-Jan	233	2	0 466	0 01	ND	0 00
7841	1	V	P	14-Jan	266	2	0 532	0 01	ND	0 00
7688	1	V	P	14-Jan	259	2	0 518	0 01	ND	0 00
7846	4	Z	P	14-Jan	243	2	0 486	0 01	ND	0 00
7947	4	Z	P	14-Jan	264	2	0 528	0 01	ND	0 00
7830	7	A	P	15-Jan	296	2	0 592	0 02	ND	0 01
7709	7	A	P	15-Jan	246	2	0 492	0 03	ND	0 01
7887	4	BB	P	15-Jan	261	2	0 522	0 00	ND	0 00
7658	4	BB	P	15-Jan	214	2	0 428	0 00	ND	0 00
7879	7	C	P	15-Jan	288 5	2	0 577	0 01	ND	0 01
7703	7	C	P	15-Jan	250 5	2	0 501	0 01	ND	0 01
7954	7	D	P	15-Jan	285 5	2	0 571	0 02	ND	0 01
7717	7	D	P	15-Jan	256 5	2	0 513	0 02	ND	0 01
7948	7	H	P	15-Jan	292 5	2	0 585	0 00	ND	0 01
7654	7	H	P	15-Jan	261 5	2	0 523	0 01	ND	0 01
7829	7	I	P	15-Jan	287	2	0 574	0 02	ND	0 01
7700	7	I	P	15-Jan	263	2	0 526	0 02	ND	0 01
7828	7	K	P	15-Jan	221	2	0 442	0 01	ND	0 01
7901	7	O	P	15-Jan	299	2	0 598	0 01	ND	0 01
7718	7	O	P	15-Jan	292	2	0 584	0 01	ND	0 01
7902	7	P	P	15-Jan	309 5	2	0 619	0 02	ND	0 01
7710	7	P	P	15-Jan	283 5	2	0 567	0 03	ND	0 01
7910	7	R	P	15-Jan	300 5	2	0 601	0 01	ND	0 01
7706	7	R	P	15-Jan	220 5	2	0 441	0 01	ND	0 01
7655	7	RT	P	15-Jan	41	2	0 082	ND	ND	0 00
7666	7	RT	P	15-Jan	21	2	0 042	ND	ND	ND
7595	7	RT	P	15-Jan	10	2	0 02	ND	ND	0 00
7667	1	U	P	15-Jan	240	2	0 48	0 01	ND	0 00
7681	1	U	P	15-Jan	293	2	0 586	ND	ND	0 00
7873	1	W	P	15-Jan	228	2	0 456	0 01	ND	0 00
7683	1	W	P	15-Jan	294	2	0 588	0 01	ND	0 00
7875	4	X	P	15-Jan	257	2	0 514	0 00	ND	0 00
7685	4	X	P	15-Jan	219	2	0 438	ND	ND	0 00
7882	4	Y	P	15-Jan	254	2	0 508	0 01	ND	0 00
7889	4	Y	P	15-Jan	215	2	0 43	0 01	ND	0 00
7693	7	A	P	16-Jan	340 5	2	0 681	0 02	ND	0 00
7733	7	A	P	16-Jan	186 5	2	0 373	0 02	ND	0 01
7715	4	AA	P	16-Jan	253	2	0 506	0 02	ND	0 00
7672	4	AA	P	16-Jan	258	2	0 516	0 01	ND	0 00
7662	7	B	P	16-Jan	337	2	0 674	0 01	ND	0 00
7584	7	B	P	16-Jan	189	2	0 378	0 01	ND	0 01
7692	4	CC	P	16-Jan	253	2	0 506	0 02	ND	0 00
7663	4	CC	P	16-Jan	258	2	0 516	0 01	ND	0 00
7905	7	D	P	16-Jan	343	2	0 686	0 01	ND	0 00
7725	7	D	P	16-Jan	191	2	0 382	0 02	ND	0 01
7652	7	H	P	16-Jan	349	2	0 698	0 01	ND	0 00
7726	7	H	P	16-Jan	189	2	0 378	0 02	ND	0 01
7678	7	I	P	16-Jan	348	2	0 696	0 01	ND	0 00
7578	7	I	P	16-Jan	188	2	0 376	0 02	ND	0 02
7602	7	K	P	16-Jan	320	2	0 64	0 01	ND	0 00
7581	7	K	P	16-Jan	202	2	0 404	0 01	ND	0 01
7594	7	O	P	16-Jan	321	2	0 642	0 00	ND	0 00

					Sample	Rate		Concentrations (mg/m3)		
Sample #	**Plant**	**Location**	**P or C**	**Date**	**Time (min)**	**(lpm)**	**Vol (m3)**	***Aluminum***	***Arsenic***	***Barium***
7593	7	O	P	16-Jan	187	2	0 374	0 01	ND	0 01
7667	7	R	P	16-Jan	321	2	0 642	0 02	ND	0 00
7597	7	R	P	16-Jan	182	2	0 364	0 01	ND	0 01
7604	7	S	P	16-Jan	348	2	0 696	0 01	ND	0 00
7574	7	S	P	16-Jan	156	2	0 312	0 01	ND	0 01
7669	1	T	P	16-Jan	244	2	0 488	0 01	ND	0 00
7590	1	T	P	16-Jan	269	2	0 538	0 01	ND	0 00
7688	1	U	P	16-Jan	240	2	0 48	0 02	0 01	0 00
7606	1	U	P	16-Jan	270	2	0 54	0 02	ND	0 00
7698	4	X	P	16-Jan	254	2	0 508	0 02	ND	0 00
7607	4	X	P	16-Jan	251	2	0 502	0 01	ND	0 00
7653	4	Y	P	16-Jan	251	2	0 502	0 01	ND	0 00
7608	4	Y	P	16-Jan	255	2	0 51	0 01	ND	0 00
7849	7	Area	na	14-Jan	289 5	2	0 579	0 00	ND	0 01
7946	7	Area	na	14-Jan	239 5	2	0 479	0 01	0 01	0 02
7852	1	Area	na	14-Jan	478	2	0 956	0 01	ND	0 00
7862	4	Area	na	14-Jan	484	2	0 968	0.00	ND	0 00
7897	7	Area	na	15-Jan	277	2	0 554	0 00	ND	0 01
7701	7	Area	na	15-Jan	1155	2	2 31	0 00	ND	0 01
7904	1	Area	na	15-Jan	451	2	0 902	0 01	ND	0 00
7903	4	Area	na	15-Jan	435	2	0 87	ND	ND	0 00
7661	7	Area	na	16-Jan	339 5	2	0 679	0 00	ND	0 00
7566	7	Area	na	16-Jan	190 5	2	0 381	0 01	0 01	0 01
7668	1	Area	na	16-Jan	552	2	1 104	0 01	ND	0 00
7707	4	Area	na	16-Jan	491	2	0 982	0 01	ND	0 00
7824	7	Blank	na	14-Jan	0	0	0	ND	ND	ND
7821	7	Blank	na	14-Jan	0	0	0	ND	ND	ND
7907	1	Blank	na	14-Jan	0	0	0	1 1 ug	ND	0 1 ug
7909	1	Blank	na	14-Jan	0	0	0	ND	ND	0 1 ug
7892	7	Blank	na	15-Jan	0	0	0	ND	ND	ND
7686	7	Blank	na	15-Jan	0	0	0	ND	ND	ND
7657	7	Blank	na	15-Jan	0	0	0	ND	ND	ND
7689	1	Blank	na	15-Jan	0	0	0	ND	ND	ND
7881	1	Blank	na	15-Jan	0	0	0	ND	ND	0 12 ug
7598	1	Blank	na	16-Jan	0	0	0	2 4 ug	ND	ND
7589	1	Blank	na	16-Jan	0	0	0	2 9 ug	ND	ND
7642	7	Blank	na	16-Jan	0	0	0	ND	ND	ND
7736	7	Blank	na	16-Jan	0	0	0	ND	ND	ND
7712	7	Blank	na	16-Jan	0	0	0	ND	ND	ND
7665	4	Blank	na	16-Jan	0	0	0	2 3 ug	ND	ND
7673	4	Blank	na	16-Jan	0	0	0	2 3 ug	ND	ND
7908	4	Blank	na	14-Jan	0	0	0	3 ug	ND	0 11 ug
7912	4	Blank	na	14-Jan	0	0	0	3 ug	ND	ND

Sample #	Berryllum	Calcium	Cadmium	Cobalt	Chromium	Copper	Iron	Lithium	Magnesium
7839	ND	0 03	ND	ND	0 00	0 01	0 68	ND	0 01
7896	ND	0 05	ND	ND	0 00	0 03	1 69	ND	0 01
7845	ND	0 16	ND	ND	0 00	0 05	2 83	ND	0 03
7880	ND	0 12	ND	ND	0 00	0 03	1 73	ND	0 02
7844	0 00	0 02	ND	ND	0 00	0 05	2 28	ND	0 00
7878	0 00	0 04	ND	0 00	0 00	0 06	2 32	ND	0 01
7855	ND	0 03	ND	ND	0 00	0 04	2 07	0 00	0 01
7958	0 00	0 04	ND	0 00	0 00	0 02	1 03	ND	0 01
7847	ND	0 03	ND	ND	0 00	0 05	2 77	0 00	0 01
7893	ND	0 05	ND	0 00	0 00	0 03	2 20	ND	0 01
7834	ND	0 02	ND	0 00	0 00	0 01	0 66	0 00	0 00
7956	0 00	0 04	ND	0 00	0 00	0 03	2 09	ND	0 01
7953	0 00	0 02	ND	ND	0 00	0 02	1 00	ND	0 00
7856	0 00	0 02	ND	ND	0 00	0 02	0 75	0 00	0 00
7827	0 00	0 01	ND	0 00	0 00	0 02	0 80	ND	0 00
7949	0 00	0 01	ND	ND	0 00	0 05	1 61	ND	0 00
7857	0 00	ND	ND	ND	ND	0 02	1 03	ND	ND
7950	0 00	0 01	ND	0 00	0 00	0 02	1 03	ND	0 00
7837	0 00	0 01	0 00	ND	ND	0 02	0 88	0 00	0 00
7886	0 00	0 01	ND	0 00	ND	0 03	1 11	ND	ND
7840	ND	0 16	ND	ND	0 00	0 07	3 81	ND	0 03
7826	ND	0 08	ND	ND	0 00	0 05	2 78	ND	0 01
7860	ND	0 14	ND	ND	0 00	0 05	2 30	ND	0 03
7861	ND	0 12	ND	ND	ND	0 01	0 72	ND	0 02
7832	ND	0 16	ND	ND	0 00	0 03	1 76	ND	0 03
7945	ND	0 11	ND	ND	0 00	0 02	1 18	0 00	0 02
7854	ND	0 17	ND	ND	0 00	0 05	2 89	ND	0 03
7884	ND	0 16	ND	ND	0 00	0 06	3 35	ND	0 03
7874	ND	0 13	ND	ND	0 00	0 03	2 46	ND	0 03
7890	ND	0 18	ND	ND	0 00	0 08	5 17	ND	0 04
7822	ND	0 10	0 00	0 00	ND	0 02	1 06	ND	0 02
7697	ND	0 09	ND	0 00	ND	0 01	0 89	ND	0 01
7911	ND	0 14	ND	0 00	0 00	0 03	1 96	ND	0 03
7684	ND	0 04	ND	ND	0 01	0 01	0 93	ND	0 01
7870	ND	0 12	0 00	0 00	0 00	0 03	1 63	ND	0 02
7680	0 00	0 09	0 00	0 00	0 00	0 05	3 54	ND	0 02
7868	0 00	0 14	0 00	0 00	0 00	0 05	2 94	0 00	0 03
7716	ND	0 11	ND	0 00	0 00	0 02	1 29	ND	0 02
7866	0 00	0 13	0 00	0 00	0 00	0 06	2 42	ND	0 02
7702	ND	0 17	ND	0 00	0 00	0 05	2 52	ND	0 03
7869	ND	0 11	ND	0 00	0 00	0 02	1 05	ND	0 02
7696	ND	0 09	ND	0 00	0 00	0 04	2 52	ND	0 02
7865	0 00	0 11	ND	0 00	0 00	0 06	3 10	ND	0 23
7704	ND	0 12	ND	0 00	0 00	0 02	1 00	ND	0 24
7900	ND	0 11	ND	ND	0 00	0 02	0 93	ND	0 02
7719	ND	0 08	ND	0 00	0 00	0 04	2 08	ND	0 02
7951	ND	0 06	ND	0 00	0 00	0 04	2 15	0 00	0 01
7708	ND	0 12	ND	0 00	0 00	0 02	1 23	ND	0 02
7705	0 00	0 37	ND	ND	ND	0 02	0 96	ND	0 09
7664	0 00	ND	ND	ND	ND	0 03	1 17	ND	ND
7899	ND	0 11	ND	0 00	0 00	0 02	1 08	0 00	0 02
7720	ND	0 09	ND	0 00	0 00	0 03	1 40	ND	0 06
7955	ND	0 09	ND	ND	0 00	0 03	1 60	ND	0 02

Sample #	Berryllum	Calcium	Cadmium	Cobalt	Chromium	Copper	Iron	Lithium	Magnesium
7695	ND	0 14	0 00	ND	0 00	0 02	1 33	ND	0 03
7943	ND	0 03	ND	ND	ND	0 04	2 26	ND	0 00
7825	ND	0 05	ND	0 00	0 00	0 04	2 55	ND	0 01
7871	ND	0 14	ND	ND	0 00	0 04	2 54	ND	0 03
7823	ND	0 10	0 00	ND	0 00	0 03	2 14	ND	0 02
7713	ND	0 17	ND	ND	0 00	0 05	3 15	ND	0 03
7671	ND	0 12	0 00	ND	0 00	0 02	1 11	ND	0 02
7694	ND	0 07	ND	0 00	0 00	0 01	0 52	ND	0 01
7596	ND	0 22	ND	0 00	0 00	0 02	1 26	ND	0 04
7601	0 00	0 13	ND	ND	0 00	0 06	3 25	ND	0 03
7641	ND	0 11	ND	0 00	0 00	0 02	1 12	ND	0 02
7618	0 00	0 14	ND	0 00	0 00	0 05	2 72	ND	0 02
7649	ND	0 19	ND	0 00	0 00	0 03	1 40	ND	0 04
7670	ND	0 08	ND	ND	0 00	0 02	0 86	ND	0 01
7583	ND	0 16	ND	ND	0 00	0 02	0 75	ND	0 03
7687	ND	0 08	ND	0 00	0 00	0 02	1 46	0 00	0 01
7592	ND	0 20	ND	0 00	0 00	0 03	1 47	0 00	0 04
7714	ND	0 10	ND	0 00	0 00	0 04	2 10	ND	0 02
7586	ND	0 21	ND	0 00	0 00	0 04	2 12	ND	0 04
7603	ND	0 11	ND	ND	0 00	0 02	1 05	ND	0 02
7587	ND	0 20	ND	ND	0 00	0 01	0 63	0 00	0 04
7610	ND	0 12	ND	0 00	0 00	0 02	1 08	ND	0 02
7600	ND	0 19	ND	ND	0 00	0 01	0 81	0 00	0 04
7675	ND	0 07	ND	ND	0 00	0 02	1 15	ND	0 01
7582	ND	0 17	ND	ND	0 00	0 04	1 68	0 00	0 03
7836	ND	0 14	ND	ND	0 00	0 05	2 87	ND	0 03
7591	0 00	0 07	ND	ND	0 00	0 05	3 00	ND	0 01
7677	ND	0 11	ND	ND	0 00	0 06	3 29	ND	0 02
7599	ND	0 04	ND	ND	0 00	0 05	2 97	ND	0 01
7699	ND	0 13	ND	ND	0 00	0 03	2 18	ND	0 02
7605	ND	0 06	ND	0 00	0 00	0 03	2 46	ND	0 01
7853	ND	0 34	ND	ND	0 00	0 06	3 75	ND	0 06
7876	ND	0 13	ND	ND	0 00	0 02	1 27	ND	0 02
7838	0 00	0 03	ND	0 00	0 00	0 01	1 05	0 00	0 00
7894	0 00	0 04	ND	ND	ND	0 02	1 16	ND	0 00
7831	ND	0 13	ND	ND	0 00	0 04	2 34	ND	0 03
7883	ND	0 12	ND	ND	0 00	0 02	1 15	ND	0 02
7851	0 00	0 01	ND	ND	ND	0 01	0 26	ND	0 00
7895	0 00	0 02	ND	ND	ND	0 01	0 36	ND	0 00
7833	ND	0 03	ND	0 00	0 00	0 03	2 27	0 00	0 01
7959	ND	0 03	ND	0 00	0 00	0 04	2 71	0 00	0 01
7835	0 00	0 03	ND	ND	0 00	0 04	2 14	0 00	0 01
7942	ND	0 06	ND	0 00	0 00	0 04	2 54	ND	0 01
7842	ND	0 03	ND	0 00	0 00	0 03	1 81	0 00	0 00
7885	ND	0 06	ND	ND	ND	0 02	1 14	ND	0 01
7863	0 00	0 01	0 00	ND	ND	0 02	0 75	0 00	0 00
7941	0 00	0 03	ND	ND	0 00	0 06	2 59	0 00	0 00
7864	0 00	0 01	ND	0 00	ND	0 00	0 17	ND	0 00
7877	0 00	0 02	ND	0 00	0 00	0 02	1 01	ND	0 00
7872	0 00	0 02	ND	0 00	ND	0 03	1 48	ND	0 00
7858	0 00	0 02	ND	ND	0 00	0 03	1 33	0 00	0 00
7843	0 00	0 01	ND	ND	ND	0 02	0 74	0 00	0 00
7957	0 00	0 01	ND	ND	0 00	0 02	0 64	ND	0 00

Sample #	Beryllium	Calcium	Cadmium	Cobalt	Chromium	Copper	Iron	Lithium	Magnesium
7848	ND	0 14	ND	ND	ND	0 02	1 06	ND	0 03
7944	ND	0 08	ND	ND	ND	0 02	0 94	ND	0 02
7841	ND	0 09	ND	ND	0 00	0 05	2 44	ND	0 01
7888	ND	0 14	ND	ND	0 00	0 04	2 12	ND	0 03
7846	ND	0 14	ND	ND	0 00	0 02	1 50	ND	0 03
7947	ND	0 08	0 00	ND	0 00	0 03	1 63	ND	0 02
7830	ND	0 09	0 00	0 00	0 00	0 02	1 00	0 00	0 02
7709	ND	0 19	ND	0 00	0 00	0 02	1 02	ND	0 04
7887	ND	0 12	ND	ND	0 00	0 03	1 63	ND	0 03
7658	ND	0 06	ND	ND	0 00	0 02	1 07	ND	0 01
7879	ND	0 14	0 00	0 00	0 00	0 04	2 25	0 00	0 03
7703	ND	0 10	ND	0 00	ND	0 01	0 90	ND	0 02
7954	ND	0 09	ND	0 00	0 00	0 01	0 98	ND	0 02
7717	ND	0 10	ND	0 00	0 00	0 01	0 58	ND	0 02
7948	0 00	0 01	ND	ND	ND	0 02	0 72	ND	0 00
7654	ND	0 12	ND	ND	0 00	0 02	0 88	ND	0 02
7829	ND	0 10	0 00	0 00	0 00	0 01	0 66	ND	0 02
7700	ND	0 10	ND	0 00	0 00	0 02	1 29	ND	0 02
7828	0 00	0 08	0 00	0 00	ND	0 02	1 15	ND	0 02
7901	ND	0 10	ND	0 00	0 00	0 02	0 85	ND	0 02
7718	0 00	0 07	ND	0 00	0 00	0 04	2 05	ND	0 01
7902	0 00	0 13	ND	0 00	0 00	0 02	1 24	0 00	0 03
7710	ND	0 14	ND	0 00	0 01	0 02	1 39	ND	0 03
7910	ND	0 13	0 00	0 00	0 00	0 03	1 46	0 00	0 02
7706	ND	0 14	ND	0 00	0 00	0 02	1 38	ND	0 03
7655	0 00	ND	ND	ND	ND	0 01	0 61	ND	ND
7666	0 00	ND	ND	ND	ND	0 02	1 10	ND	ND
7595	0 00	ND	ND	ND	ND	0 02	0 95	ND	ND
7867	ND	0 16	ND	ND	0 00	0 06	3 54	ND	0 03
7681	ND	0 01	ND	ND	ND	0 02	1 35	ND	0 00
7873	ND	0 14	ND	0 00	ND	0 02	1 10	ND	0 03
7683	ND	0 05	ND	0 00	0 00	0 03	1 87	ND	0 01
7875	ND	0 13	0 00	ND	0 00	0 01	0 60	ND	0 03
7685	ND	0 03	0 00	0 00	ND	0 01	0 50	ND	0 01
7882	ND	0 14	ND	ND	0 00	0 03	1 85	ND	0 03
7889	ND	0 15	ND	ND	0 00	0 03	1 60	ND	0 03
7693	ND	0 08	ND	0 00	0 00	0 02	1 07	ND	0 01
7733	ND	0 10	ND	ND	0 00	0 03	2 09	ND	0 02
7715	ND	0 16	ND	ND	0 00	0 04	2 57	ND	0 03
7672	ND	0 05	0 00	ND	0 00	0 02	1 65	ND	0 01
7662	ND	0 06	ND	ND	0 00	0 01	0 49	ND	0 01
7584	ND	0 21	ND	ND	0 00	0 01	0 63	0 00	0 04
7692	ND	0 12	ND	ND	0 00	0 04	2 96	ND	0 02
7663	ND	0 04	ND	ND	0 00	0 01	0 62	ND	0 01
7905	ND	0 10	ND	0 00	0 00	0 01	0 54	ND	0 02
7725	ND	0 11	ND	ND	ND	0 01	0 63	ND	0 02
7652	ND	0 12	0 00	0 00	0 00	0 03	1 86	ND	0 02
7726	ND	0 12	ND	0 00	0 00	0 03	2 22	ND	0 02
7678	ND	0 07	ND	0 00	0 00	0 01	0 76	ND	0 01
7578	ND	0 22	ND	0 00	0 00	0 02	0 98	ND	0 04
7602	0 00	0 14	ND	ND	0 00	0 02	1 28	ND	0 03
7581	ND	0 19	ND	0 00	0 00	0 02	1 06	0 00	0 04
7594	ND	0 11	ND	ND	0 00	0 01	0 64	ND	0 02

Sample #	Beryllium	Calcium	Cadmium	Cobalt	Chromium	Copper	Iron	Lithium	Magnesium
7593	ND	0 18	ND	ND	0 00	0 03	1 74	0 00	0 04
7667	0 00	0 07	ND	0 00	0 00	0 04	2 18	ND	0 01
7597	ND	0 19	ND	ND	0 00	0 02	0 85	0 00	0 04
7604	ND	0 10	ND	ND	0 00	0 01	0 55	ND	0 02
7574	ND	0 23	ND	ND	ND	0 01	0 58	0 00	0 04
7669	ND	0 05	0 00	ND	ND	0 02	0 96	ND	0 00
7590	ND	0 15	ND	ND	0 00	0 02	0 99	ND	0 03
7688	ND	0 10	ND	ND	0 00	0 05	2 71	ND	0 02
7606	ND	0 14	ND	ND	0 00	0 04	2 41	ND	0 03
7698	ND	0 11	ND	0 00	ND	0 01	0 71	ND	0 02
7607	ND	0 17	ND	ND	0 00	0 01	0 50	ND	0 03
7653	ND	0 22	ND	ND	0 00	0 03	1 83	ND	0 04
7608	ND	0 19	ND	ND	0 00	0 03	1 69	ND	0 04
7849	0 00	0 02	ND	ND	ND	0 01	0 43	ND	0 00
7946	0 00	0 03	ND	ND	ND	0 01	0 71	ND	0 00
7852	ND	0 09	ND	ND	0 00	0 02	1 15	ND	0 02
7862	ND	0 07	ND	ND	ND	0 01	0 40	ND	0 01
7897	ND	0 02	ND	0 00	ND	0 01	0 54	0 00	0 00
7701	ND	0 02	ND	ND	0 00	0 01	0 37	ND	0 00
7904	ND	0 05	ND	ND	0 00	0 02	1 11	ND	0 01
7903	ND	0 07	0 00	ND	ND	0 00	0 26	ND	0 01
7681	ND	0 02	ND	ND	0 00	0 01	0 41	ND	0 00
7566	0 00	0 02	ND	0 00	0 00	0 01	0 45	ND	0 00
7668	ND	0 06	ND	ND	0 00	0 02	1 36	ND	0 01
7707	ND	0 08	ND	0 00	ND	0 00	0 22	ND	0 01
7824	0 026 ug	ND	ND	ND	ND	0 1 ug	2 9 ug	ND	ND
7821	0 024 ug	ND	0 081 ug	ND	ND	ND	1 3 ug	ND	ND
7907	ND	58 ug	ND	ND	ND	0 19 ug	1 9 ug	ND	11 ug
7909	ND	56 ug	ND	ND	ND	0 15 ug	2 ug	ND	11 ug
7892	0 028 ug	ND	ND	ND	ND	ND	1 2 ug	ND	ND
7686	ND	ND	ND	ND	ND	ND	0 89 ug	ND	ND
7657	0 022 ug	ND	0 081 ug	ND	ND	0 09 ug	0 89 ug	ND	ND
7689	ND	ND	ND	ND	ND	ND	3 ug	ND	0 69 ug
7881	ND	51 ug	ND	ND	ND	0 29 ug	6 1 ug	ND	12 ug
7598	ND	6 4 ug	ND	ND	0 52 ug	ND	19 ug	ND	ND
7589	ND	7 ug	0 09 ug	ND	ND	0 11 ug	21 ug	ND	1 2 ug
7642	0 022 ug	ND	ND	ND	ND	ND	ND	ND	ND
7736	0 022 ug	ND	ND	0 28 ug	ND	ND	ND	ND	ND
7712	0 024 ug	ND	ND	ND	ND	ND	ND	ND	ND
7665	ND	5 ug	0 085 ug	ND	ND	ND	6 9 ug	ND	0 75 ug
7673	ND	7 2 ug	ND	ND	ND	ND	3 1 ug	ND	ND
7908	ND	56 ug	ND	ND	ND	0 19 ug	3 2 ug	ND	11 ug
7912	ND	5 4 ug	0 099 ug	ND	ND	ND	1 3 ug	ND	0 62 ug

Sample #	Manganese	Molybdenum	Nickel	Lead	Phosphorus	Platinum	Selenium	Silver	Sodium
7839	0 07	ND	0 00	ND	0 01	ND	0 01	ND	0 02
7896	0 20	ND	0 01	ND	0 01	ND	ND	0 00	0 02
7845	0 32	0 00	0 00	ND	ND	ND	ND	0 00	0 04
7880	0 21	0 00	ND	ND	0 01	ND	ND	ND	0 04
7844	0 36	ND	0 00	ND	0 01	ND	0 00	0 00	0 02
7878	0 37	ND	0 00	ND	0 01	ND	ND	ND	0 03
7855	0 28	ND	0 00	ND	0 15	ND	0 00	ND	0 02
7958	0 10	ND	0 01	ND	0 00	ND	ND	ND	0 02
7847	0 52	ND	0 01	ND	0 00	ND	ND	0 00	0 02
7893	0 28	ND	0 01	ND	0 01	ND	ND	ND	0 02
7834	0 07	ND	0 00	ND	0 01	ND	ND	ND	0 02
7956	0 21	ND	0 01	0 00	0 01	ND	ND	ND	0 02
7953	0 10	ND	0 00	ND	0 01	ND	0 01	ND	0 02
7856	0 09	ND	0 00	ND	ND	ND	ND	ND	0 02
7827	0 08	0 00	0 00	ND	ND	ND	ND	ND	0 01
7949	0 18	ND	0 00	0 00	ND	ND	ND	ND	0 01
7857	0 08	ND	ND	ND	ND	ND	ND	ND	0 02
7950	0 08	ND	0 00	0 00	ND	ND	ND	ND	0 02
7837	0 09	0 00	0 00	ND	ND	ND	ND	ND	0 01
7886	0 11	ND	0 00	ND	ND	ND	ND	ND	0 01
7840	0 53	0 00	ND	ND	0 01	ND	ND	0 00	0 07
7826	0 41	0 00	ND	ND	0 01	0 00	ND	0 00	0 04
7860	0 23	0 00	0 00	ND	ND	ND	ND	ND	0 04
7861	0 07	0 00	ND	ND	0 01	ND	ND	ND	0 04
7832	0 21	0 00	ND	ND	0 01	ND	ND	ND	0 05
7945	0 15	0 00	ND	ND	0 01	ND	ND	ND	0 06
7854	0 39	0 00	0 00	0 00	0 00	ND	ND	0 00	0 05
7884	0 43	ND	0 00	ND	0 01	ND	ND	0 00	0 06
7874	0 21	ND	0 00	0 00	ND	ND	ND	0 00	0 04
7890	0 55	ND	0 00	ND	ND	ND	ND	0 00	0 04
7822	0 12	ND	0 00	ND	ND	ND	ND	ND	0 02
7697	0 11	ND	0 00	0 00	0 00	ND	ND	ND	0 03
7911	0 24	ND	ND	0 00	ND	ND	ND	ND	0 04
7684	0 08	0 00	0 00	ND	ND	ND	ND	ND	0 03
7870	0 21	ND	0 00	ND	0 01	ND	ND	0 00	0 03
7680	0 45	ND	0 00	0 00	ND	ND	ND	0 00	0 04
7868	0 28	0 00	0 00	0 00	0 01	ND	ND	0 00	0 04
7716	0 12	ND	0 00	0 00	0 01	ND	ND	ND	0 01
7866	0 41	ND	0 00	0 00	0 00	0 01	ND	0 00	0 02
7702	0 35	0 00	0 01	0 00	0 01	ND	ND	ND	0 04
7869	0 13	ND	0 00	ND	0 00	ND	ND	0 00	0 02
7696	0 37	ND	0 00	ND	0 01	0 01	ND	0 00	0 04
7865	0 34	ND	0 00	0 00	ND	ND	ND	ND	0 03
7704	0 12	ND	0 00	0 00	0 01	ND	ND	ND	0 03
7900	0 09	ND	0 00	ND	ND	ND	ND	0 00	0 03
7719	0 24	ND	0 00	ND	0 01	ND	ND	0 00	0 06
7951	0 31	ND	0 00	0 00	ND	ND	ND	0 00	0 03
7708	0 17	0 00	0 00	ND	0 00	ND	ND	0 00	0 03
7705	0 12	ND	ND	ND	ND	ND	ND	ND	0 19
7664	0 19	ND	ND	0 03	ND	ND	ND	ND	0 11
7899	0 15	ND	0 00	ND	0 01	ND	ND	0 00	0 03
7720	0 17	ND	0 00	ND	0 01	ND	ND	0 00	0 05
7955	0 21	0 00	0 00	0 00	0 01	ND	ND	ND	0 08

Sample #	Manganese	Molybdenum	Nickel	Lead	Phosphorus	Platinum	Selenium	Silver	Sodium
7695	0 15	0 00	ND	0 00	0 02	ND	ND	ND	0 07
7943	0 25	ND	ND	ND	ND	ND	ND	ND	0 03
7825	0 31	ND	0 00	ND	ND	0 01	ND	ND	0 02
7871	0 35	ND	ND	ND	ND	ND	ND	ND	0 04
7823	0 30	ND	ND	0 00	ND	ND	ND	ND	0 05
7713	0 24	0 00	0 00	0 00	ND	ND	ND	ND	0 04
7671	0 12	0 00	0 00	0 00	ND	ND	ND	ND	0 04
7694	0 05	ND	0 00	ND	0 02	ND	ND	0 00	0 06
7596	0 16	ND	0 00	ND	0 02	ND	ND	0 00	0 07
7601	0 42	ND	0 00	ND	0 01	ND	ND	0 00	0 05
7641	0 12	ND	0 00	ND	0 01	ND	ND	ND	0 05
7618	0 29	0 00	0 00	ND	0 02	ND	ND	ND	0 05
7649	0 13	ND	0 00	ND	0 02	ND	ND	0 00	0 06
7670	0 11	ND	ND	ND	0 01	ND	ND	ND	0 04
7583	0 10	ND	0 00	ND	0 01	ND	ND	ND	0 04
7687	0 14	ND	0 00	ND	0 01	ND	ND	ND	0 04
7592	0 15	ND	0 00	ND	0 01	ND	ND	ND	0 06
7714	0 22	ND	0 00	ND	0 01	ND	ND	ND	0 03
7586	0 25	ND	0 00	0 00	0 01	ND	ND	0 00	0 05
7603	0 12	0 00	ND	ND	ND	ND	ND	ND	0 04
7587	0 06	0 00	ND	ND	0 01	ND	ND	ND	0 06
7610	0 11	ND	0 00	ND	0 01	ND	ND	ND	0 05
7600	0 07	ND	0 00	ND	ND	ND	ND	ND	0 08
7675	0 16	0 00	0 00	ND	ND	ND	ND	ND	0 04
7582	0 24	0 00	ND	ND	ND	ND	ND	ND	0 06
7836	0 33	0 00	0 00	0 00	0 00	ND	ND	0 00	0 05
7591	0 32	0 00	0 00	0 00	0 00	ND	ND	ND	0 02
7677	0 35	ND	0 00	0 00	0 01	ND	ND	0 00	0 05
7599	0 30	0 00	0 00	0 00	0 00	ND	ND	ND	0 01
7699	0 26	ND	0 00	0 00	ND	ND	ND	ND	0 03
7605	0 28	ND	ND	0 00	ND	ND	ND	ND	0 02
7853	0 53	0 00	ND	ND	0 02	ND	ND	ND	0 22
7876	0 18	0 00	0 00	ND	0 00	ND	ND	ND	0 05
7838	0 07	ND	0 00	ND	0 01	ND	ND	ND	0 02
7894	0 10	ND	0 01	0 00	0 01	ND	ND	ND	0 02
7831	0 41	ND	ND	0 00	ND	ND	ND	0 00	0 05
7883	0 18	ND	0 00	ND	ND	ND	ND	ND	0 03
7851	0 03	ND	ND	ND	ND	ND	ND	ND	0 01
7895	0 04	0 00	0 00	ND	ND	ND	ND	ND	0 01
7833	0 17	ND	0 01	ND	0 01	0 01	ND	0 00	0 02
7959	0 21	ND	0 01	ND	0 01	ND	ND	ND	0 03
7835	0 38	ND	0 00	ND	0 01	ND	ND	0 00	0 03
7942	0 20	ND	0 01	ND	0 01	ND	0 01	ND	0 03
7642	0 23	ND	0 00	0 00	0 00	ND	ND	ND	0 02
7885	0 13	ND	0 00	ND	0 02	ND	ND	ND	0 07
7863	0 07	0 00	0 00	ND	ND	ND	ND	ND	0 01
7941	0 23	ND	0 00	ND	ND	ND	ND	ND	0 02
7864	0 01	ND	0 00	ND	0 01	ND	0 00	ND	0 01
7877	0 11	ND	0 01	0 00	0 01	ND	ND	ND	0 02
7872	0 23	ND	0 01	ND	ND	0 01	ND	ND	0 02
7858	0 21	ND	0 00	ND	0 00	ND	ND	ND	0 01
7843	0 16	ND	0 00	ND	ND	ND	ND	ND	0 01
7957	0 11	ND	0 00	ND	ND	ND	ND	ND	0 01

Sample #	Manganese	Molybdenum	Nickel	Lead	Phosphorus	Platinum	Selenium	Silver	Sodium
7648	0 14	0 00	ND	ND	0 01	ND	ND	ND	0 06
7944	0 14	0 00	ND	ND	0 01	ND	ND	ND	0 05
7641	0 30	0 00	0 00	ND	0 00	ND	ND	ND	0 05
7888	0 29	0 00	ND	ND	0 01	ND	ND	0 00	0 05
7846	0 27	ND	ND	0 00	ND	ND	ND	0 00	0 04
7947	0 23	ND	0 00	ND	ND	ND	ND	ND	0 05
7830	0 15	ND	0 00	0 00	0 01	ND	ND	ND	0 02
7709	0 16	ND	0 00	ND	0 00	ND	ND	0 00	0 05
7887	0 23	ND	ND	0 00	ND	0 01	ND	ND	0 04
7658	0 14	ND	ND	ND	ND	ND	ND	ND	0 02
7879	0 42	ND	0 00	ND	0 01	ND	ND	ND	0 03
7703	0 11	ND	0 00	ND	ND	ND	ND	ND	0 01
7954	0 09	ND	0 00	ND	0 01	ND	ND	ND	0 04
7717	0 06	ND	0 00	0 00	0 01	ND	ND	ND	0 04
7948	0 11	0 00	0 00	ND	ND	ND	ND	ND	0 01
7654	0 15	ND	0 00	ND	0 00	ND	ND	ND	0 02
7829	0 09	ND	0 01	0 00	0 01	ND	ND	0 00	0 03
7700	0 14	ND	0 01	0 00	0 01	ND	ND	ND	0 03
7828	0 17	ND	0 00	0 00	0 01	ND	ND	ND	0 03
7901	0 09	ND	0 00	0 00	ND	ND	ND	0 00	0 03
7718	0 34	ND	0 00	ND	0 01	ND	ND	0 00	0 03
7902	0 11	ND	0 00	0 00	0 00	ND	ND	ND	0 03
7710	0 17	0 00	0 01	ND	0 01	ND	ND	0 00	0 03
7910	0 25	ND	0 00	ND	0 00	ND	ND	0 00	0 06
7706	0 22	ND	0 00	ND	0 01	ND	ND	0 00	0 05
7655	0 10	0 00	ND	ND	ND	ND	ND	ND	0 03
7666	0 21	ND	ND	0 02	ND	ND	ND	ND	0 05
7595	0 21	ND	ND	ND	ND	ND	ND	ND	0 13
7867	0 46	0 00	0 00	0 00	0 01	ND	ND	0 00	0 07
7681	0 20	0 00	0 00	0 00	ND	ND	ND	ND	0 01
7873	0 11	ND	ND	ND	ND	ND	ND	ND	0 05
7683	0 26	0 00	0 00	ND	0 00	ND	ND	0 00	0 03
7875	0 10	0 00	ND	0 00	ND	ND	ND	ND	0 04
7685	0 06	0 00	ND	ND	ND	ND	ND	ND	0 03
7882	0 30	0 00	ND	0 00	ND	ND	ND	ND	0 05
7889	0 26	0 00	ND	0 00	0 00	0 01	ND	0 00	0 06
7693	0 14	ND	0 00	#DIV/0!	0 01	ND	ND	ND	0 04
7733	0 27	ND	0 00	0 00	0 01	ND	ND	ND	0 06
7715	0 36	0 00	ND	0 00	ND	ND	ND	0 00	0 05
7672	0 19	ND	ND	0 00	ND	ND	ND	ND	0 02
7662	0 05	0 00	ND	ND	0 01	ND	ND	ND	0 04
7584	0 07	0 00	0 00	ND	0 01	ND	ND	ND	0 06
7692	0 45	ND	ND	0 00	ND	ND	ND	ND	0 05
7663	0 09	ND	ND	0 00	ND	ND	ND	ND	0 00
7905	0 04	ND	0 00	ND	0 02	ND	ND	ND	0 05
7725	0 07	0 00	0 00	ND	0 03	ND	ND	ND	0 07
7652	0 23	0 00	0 00	0 00	0 01	ND	ND	0 00	0 05
7726	0 14	0 00	0 01	0 00	0 02	ND	ND	ND	0 06
7678	0 08	ND	0 00	0 00	0 01	ND	ND	ND	0 03
7578	0 09	ND	0 01	ND	0 01	ND	ND	0 00	0 08
7602	0 17	ND	0 00	ND	0 01	ND	ND	ND	0 04
7581	0 15	ND	0 00	ND	ND	ND	ND	0 00	0 05
7594	0 07	ND	ND	ND	0 00	ND	ND	ND	0 04

Sample #	**Manganese**	**Molybdenum**	**Nickel**	**Lead**	**Phosphorus**	**Platinum**	**Selenium**	**Silver**	**Sodium**
7593	0 27	0 00	0 00	ND	0 01	ND	ND	ND	0 08
7687	0 39	ND	ND	0 00	0 00	ND	ND	0 00	0 06
7597	0 10	0 00	ND	ND	ND	ND	ND	ND	0 07
7604	0 07	0 00	ND	ND	ND	ND	ND	ND	0 04
7574	0 07	0 00	ND	ND	ND	ND	ND	ND	0 09
7669	0 12	0 00	ND	ND	ND	ND	ND	ND	0 01
7590	0 12	0 00	ND	0 00	ND	ND	ND	ND	0 07
7688	0 38	ND	0 00	ND	ND	0 01	ND	ND	0 05
7606	0 30	0 00	ND	0 00	0 01	ND	ND	ND	0 06
7698	0 11	ND	ND	0 00	ND	ND	ND	ND	0 05
7607	0 08	0 00	ND	0 00	ND	ND	ND	ND	0 05
7653	0 30	ND	ND	0 00	ND	ND	ND	0 00	0 04
7608	0 27	0 00	ND	0 00	0 01	ND	ND	ND	0 04
7849	0 04	ND	0 00	ND	0 01	ND	ND	ND	0 02
7946	0 08	ND	0 00	ND	0 01	ND	0 01	ND	0 02
7852	0 15	0 00	0 00	ND	0 01	ND	ND	ND	0 03
7862	0 03	0 00	0 00	ND	ND	ND	ND	ND	0 02
7897	0 07	ND	0 00	ND	0 00	ND	0 00	ND	0 01
7701	0 05	ND	0 00	ND	0 00	ND	ND	ND	0 01
7904	0 13	0 00	ND	ND	0 01	ND	ND	ND	0 01
7903	0 03	ND	ND	ND	ND	ND	ND	ND	0 02
7681	0 05	ND	0 00	ND	0 01	ND	ND	ND	0 01
7566	0 06	ND	0 00	ND	ND	ND	0 01	ND	0 02
7868	0 17	0 00	ND	ND	0 00	ND	ND	ND	0 03
7707	0 03	ND	ND	ND	ND	ND	ND	ND	0 02
7824	0 28 ug	ND	ND	ND	ND	ND	ND	ND	3 3 ug
7821	0 069 ug	ND	ND	ND	ND	ND	ND	ND	3 5 ug
7907	0 15 ug	ND	ND	ND	ND	ND	ND	ND	26 ug
7909	0 039 ug	0 48 ug	ND	ND	ND	ND	ND	ND	20 ug
7892	0 044 ug	ND	ND	ND	ND	ND	ND	ND	2 8 ug
7666	ND	ND	ND	ND	ND	ND	ND	ND	4 6 ug
7657	0 036 ug	ND	ND	ND	ND	ND	ND	ND	2 3 ug
7689	0 054 ug	0 89 ug	ND	ND	ND	ND	ND	ND	ND
7881	0 048 ug	ND	ND	0 56 ug	ND	ND	ND	ND	16 ug
7598	ND	ND	0 52 ug	0 56 ug	ND	ND	ND	ND	ND
7589	ND	ND	ND	ND	ND	ND	ND	ND	5 2 ug
7642	0 036 ug	ND	ND	ND	ND	ND	ND	ND	2 2 ug
7736	0 019 ug	ND	ND	ND	ND	ND	ND	ND	ND
7712	0 036 ug	ND	ND	ND	ND	ND	ND	ND	ND
7665	ND	ND	ND	ND	ND	ND	ND	ND	2 7 ug
7673	ND	ND	ND	0 62 ug	ND	ND	ND	ND	ND
7908	ND	ND	ND	ND	ND	ND	ND	ND	22 ug
7912	ND	ND	ND	ND	ND	ND	ND	ND	4 1 ug

Sample #	Tellurium	Thallium	Titanium	Vanadium	Yttrium	Zinc	Zirconium
7839	ND	ND	ND	ND	ND	0 01	0 00
7896	ND	ND	0 00	ND	ND	0 01	0 00
7845	ND	ND	0 00	ND	ND	0 02	ND
7880	0 00	ND	0 00	ND	ND	0 02	ND
7844	ND	ND	0 00	ND	ND	0 01	ND
7878	ND	ND	0 00	ND	ND	0 01	0 00
7855	ND	ND	0 00	ND	ND	0 01	ND
7958	ND	ND	0 00	ND	ND	0 01	0 00
7847	0 00	ND	0 00	0 00	ND	0 03	ND
7893	ND	ND	0 00	0 00	ND	0 01	ND
7834	ND	ND	0 00	ND	ND	0 00	ND
7956	0 00	ND	0 00	ND	ND	0 01	ND
7953	0 00	ND	0 00	ND	ND	0 00	ND
7856	ND	ND	0 00	ND	ND	0 00	ND
7827	ND	ND	ND	ND	ND	0 00	0 00
7949	ND	ND	ND	ND	ND	0 01	0 00
7857	ND	ND	ND	ND	ND	ND	ND
7950	ND	ND	ND	ND	ND	0 00	ND
7837	ND	ND	ND	ND	ND	0 00	ND
7886	ND	ND	ND	ND	ND	0 00	ND
7840	ND	ND	0 01	ND	ND	0 03	0 00
7826	ND	ND	0 00	ND	ND	0 02	ND
7860	ND	ND	0 00	ND	ND	0 01	ND
7861	ND	ND	ND	ND	ND	0 00	0 00
7832	ND	ND	ND	ND	ND	0 01	ND
7945	ND	ND	0 00	0 00	ND	0 01	ND
7854	ND	ND	0 00	ND	ND	0 01	ND
7884	ND	ND	0 00	ND	ND	0 01	0 00
7874	ND	ND	0 00	ND	ND	0 01	0 00
7890	ND	ND	0 00	ND	ND	0 03	0 00
7822	ND	ND	0 00	ND	ND	0 01	0 00
7697	ND	ND	0 00	0 00	ND	0 00	0 00
7911	ND	ND	0 00	ND	ND	0 01	0 00
7684	ND	ND	0 00	ND	ND	0 01	0 00
7870	0 00	ND	0 00	ND	ND	0 01	0 00
7680	ND	ND	0 00	ND	ND	0 01	0 00
7868	ND	ND	0 00	0 00	ND	0 01	0 00
7716	ND	ND	0 00	ND	ND	0 00	0 00
7866	0 00	ND	0 00	ND	ND	0 01	0 00
7702	ND	ND	0 00	ND	ND	0 01	0 00
7869	ND	ND	0 00	ND	ND	0 01	0 00
7696	ND	ND	0 00	ND	ND	0 01	0 00
7865	ND	ND	0 00	ND	ND	0 01	0 00
7704	ND	ND	0 00	ND	ND	0 01	0 00
7900	ND	ND	ND	ND	ND	0 01	0 00
7719	ND	ND	0 00	ND	ND	0 01	0 00
7951	0 00	ND	0 00	0 00	ND	0 01	0 00
7708	0 00	ND	0 00	0 00	ND	0 01	0 00
7705	ND	ND	ND	ND	ND	ND	ND
7664	ND	ND	ND	ND	ND	ND	ND
7899	ND	ND	ND	ND	ND	0 01	0 00
7720	ND	ND	0 00	ND	ND	0 01	0 00
7955	ND	ND	0 00	ND	ND	0 01	0 00

Sample #	Tellurium	Thallium	Titanium	Vanadium	Yttrium	Zinc	Zirconium
7695	ND	ND	0 00	ND	ND	0 01	0 00
7943	ND	ND	0 00	ND	ND	0 02	0 00
7825	ND	ND	0 00	ND	ND	0 02	0 00
7871	ND	ND	0 00	ND	ND	0 01	0 00
7823	ND	ND	0 00	ND	ND	0 01	0 00
7713	ND	ND	0 00	ND	ND	0 03	ND
7671	ND	ND	0 00	ND	ND	0 01	0 00
7694	ND	ND	0 00	ND	ND	0 00	0 00
7596	ND	ND	0 00	ND	ND	0 01	0 00
7601	ND	ND	0 00	ND	ND	0 02	0 00
7641	ND	ND	0 00	ND	ND	0 01	0 00
7618	ND	ND	0 00	ND	ND	0 01	0 00
7649	ND	ND	0 00	ND	ND	0 01	0 00
7670	ND	ND	0 00	ND	ND	0 01	0 00
7583	ND	ND	0 00	ND	ND	0 01	0 00
7687	0 00	ND	0 00	0 00	ND	0 01	0 00
7592	ND	ND	0 00	ND	ND	0 01	0 00
7714	ND	ND	0 00	ND	ND	0 01	0 00
7586	ND	ND	0 00	ND	ND	0 01	0 00
7603	0 00	ND	#VALUE!	ND	ND	0 01	ND
7587	ND	ND	ND	ND	ND	0 00	ND
7610	ND	ND	0 00	ND	ND	0 01	0 00
7600	ND	ND	0 00	ND	ND	0 01	0 00
7675	ND	ND	0 00	ND	ND	0 01	ND
7582	ND	ND	ND	ND	ND	0 01	ND
7836	ND	ND	0 00	ND	ND	0 02	0 00
7591	ND	ND	0 00	ND	ND	0 02	0 00
7677	ND	ND	0 00	ND	ND	0 02	0 00
7599	ND	ND	0 00	ND	ND	0 02	0 00
7699	ND	ND	0 03	ND	ND	0 01	0 00
7605	ND	ND	0 00	ND	ND	0 01	0 00
7853	ND	ND	ND	ND	ND	0 01	0 00
7676	ND	ND	ND	0 00	ND	0 01	0 00
7838	ND	ND	0 00	ND	ND	0 00	ND
7894	ND	ND	0 00	ND	ND	0 01	ND
7831	ND	ND	0 00	ND	ND	0 01	0 00
7883	ND	ND	0 00	ND	ND	0 01	0 00
7851	ND	ND	ND	ND	ND	ND	0 00
7895	ND	ND	ND	0 00	ND	ND	0 00
7833	ND	ND	0 00	ND	ND	0 01	ND
7959	ND	ND	0 00	ND	ND	0 01	ND
7835	ND	ND	0 00	ND	ND	0 01	ND
7942	ND	ND	0 00	ND	ND	0 02	ND
7842	0 00	ND	0 00	ND	ND	0 01	0 00
7885	ND	ND	ND	ND	ND	0 01	0 00
7863	ND	ND	ND	ND	ND	0 00	0 00
7941	ND	ND	ND	ND	ND	0 01	0 00
7864	ND	ND	ND	ND	ND	0 00	0 00
7877	ND	ND	0 00	ND	ND	0 00	0 00
7872	0 00	ND	ND	ND	ND	0 01	ND
7858	ND	ND	0 00	ND	ND	0 01	ND
7843	ND	ND	ND	ND	ND	0 01	ND
7957	0 00	ND	ND	ND	ND	0 00	ND

Sample #	Tellurium	Thallium	Titanium	Vanadium	Yttrium	Zinc	Zirconium
7848	ND	ND	0 00	ND	ND	0 01	ND
7944	ND	ND	0 00	ND	ND	0 01	ND
7841	ND	ND	0 00	ND	ND	0 02	ND
7888	ND	ND	0 00	ND	ND	0 02	ND
7846	ND	ND	0 00	ND	ND	0 01	0 00
7947	ND	ND	0 00	ND	ND	0 01	0 00
7830	ND	ND	0 00	ND	ND	0 01	0 00
7709	0 00	ND	0 00	0 00	ND	0 01	0 00
7887	ND	ND	0 00	ND	ND	0 01	0 00
7658	ND	ND	0 00	ND	ND	0 01	0 00
7879	ND	ND	0 00	ND	ND	0 03	0 00
7703	ND	ND	0 00	ND	ND	0 01	0 00
7954	ND	ND	0 00	ND	ND	0 01	0 00
7717	0 00	ND	0 00	ND	ND	0 00	0 00
7948	ND	ND	ND	ND	ND	0 01	0 00
7654	ND	ND	0 00	ND	ND	0 01	0 00
7829	0 00	ND	0 00	ND	ND	0 01	0 00
7700	ND	ND	0 00	ND	ND	0 01	0 00
7828	ND	ND	0 00	ND	ND	0 01	0 00
7901	ND	ND	0 00	ND	ND	0 01	0 00
7718	ND	ND	0 00	ND	ND	0 03	0 00
7902	ND	ND	0 00	ND	ND	0 01	0 00
7710	0 00	ND	0 00	ND	ND	0 01	0 00
7910	ND	ND	0 00	ND	ND	0 01	0 00
7706	ND	ND	0 00	ND	ND	0 01	0 00
7656	ND	ND	ND	0 00	ND	ND	ND
7666	ND	ND	ND	ND	ND	ND	ND
7595	0 06	ND	ND	ND	ND	ND	ND
7867	ND	ND	0 00	ND	ND	0 03	0 00
7681	ND	ND	0 00	ND	ND	0 02	0 00
7873	ND	ND	0 00	ND	ND	0 01	0 00
7683	ND	ND	0 00	0 00	ND	0 01	0 00
7875	ND	ND	0 00	ND	ND	0 00	0 00
7685	ND	ND	ND	ND	ND	0 00	0 00
7882	ND	ND	0 00	0 00	ND	0 01	0 00
7889	ND	ND	0 00	ND	ND	0 01	0 00
7693	ND	ND	0 00	ND	ND	0 01	0 00
7733	ND	ND	0 00	ND	ND	0 03	0 00
7715	ND	ND	0 00	ND	ND	0 01	0 00
7672	ND	ND	0 00	ND	ND	0 01	0 00
7662	ND	ND	ND	ND	ND	0 00	ND
7584	ND	ND	ND	ND	ND	0 01	ND
7692	ND	ND	0 00	ND	ND	0 01	0 00
7663	ND	ND	ND	ND	ND	0 00	0 00
7905	ND	ND	0 00	ND	ND	0 00	0 00
7725	0 00	ND	ND	ND	ND	0 00	0 00
7652	ND	ND	0 00	ND	ND	0 01	0 00
7726	0 00	ND	0 00	ND	ND	0 01	0 00
7678	ND	ND	0 00	ND	ND	0 01	0 00
7578	ND	ND	0 00	ND	ND	0 01	0 00
7602	ND	ND	0 00	ND	ND	0 01	0 00
7581	ND	ND	0 00	ND	ND	0 01	0 00
7594	ND	ND	ND	ND	ND	0 01	ND

At the time of the NIOSH study at Vermeer, welders worked five ten-hour days per week The Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs) and the American Conference of Governmental Industrial Hygienists (ACGIH®) Threshold Limit Values (TLVs®) represent time weighted average (TWA) concentrations of atmospheric contaminants for a conventional 8-hour workday and a 40-hour workweek, to which nearly all workers may be repeatedly exposed, day after day, without adverse effect [1,2] The NIOSH Recommended Exposure Limits (RELs) are TWA concentrations for up to a 10-hour day during a 40-hour workweek [3] Because a longer workday or workweek not only implies an increase in the time the worker is exposed to the contaminant, but a decreased recovery time away from that exposure, these exposure criteria are often adjusted to account for these differences [4] Several models have been developed for making these adjustments, as well as a list of rules of thumb [4] A model developed by Brief and Scala was applied to adjust the PELs and TLVs for the contaminants measured during the study at Vermeer [4,5]

The model developed by Brief and Scala contains a set of conditions which must be considered in its application Foremost among these conditions is consideration of the basis of the exposure criteria Where the exposure criterion is based on a systemic effect of the contaminant, either acute or chronic, then the reduction factor resulting from application of the model will be considered as a TWA Brief and Scala further divide acute effects into those that are rapid with immediate onset, and those that manifest with time during a single exposure They consider the former to be guarded by the C notation in the exposure criteria, and the latter are considered to be time and concentration dependent, and thus both cases are amenable to the use of their model Number of days worked per week is not considered in their model, except for a 7-day workweek Furthermore, they did not view their model to be applicable to either 24-hour continuous exposures or to work schedules less than seven to eight hours per day or 35 hours per week. Finally, where the exposure criterion is based solely on sensory irritation, Brief and Scala state that the irritation response threshold is unlikely to be altered downward by an increase in the number of hours worked, and no modification is needed [5]

For adjustment of TLVs and PELs, the reduction factor (RF) is expressed as

$$RF = 8/h \times [(24-h)/16]$$

Where h is the number of hours worked per day [5]

Thus, for a 10-hour, 5-day work schedule, the ACGIH TLVs and OSHA PELs should be reduced by a factor of 0 7

References

1 58 Fed Reg 35338 [1993] Occupational Safety and Health Administration air contaminants, final rule (To be codified at 29 CFR 1910)

2 ACGIH [1996] 1996 threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH American Conference of Governmental Industrial Hygienists

3 NIOSH [1994] NIOSH pocket guide to chemical hazards Cincinnati, OH U S

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4. Paustenbach DJ [1994] Occupational exposure limits, pharmacokinetics, and unusual work schedules Chapter 7 In Harris RL, Cralley LJ, Cralley LV, eds Patty's industrial hygiene and toxicology, 3rd rev ed Vol 3, Part A, New York, NY John Wiley and Sons, Inc

5 Brief RS, Scala RA [1975] Occupational exposure limits for novel work schedules Am Ind Hyg Assoc J <u>*36*</u> 467-471

Table 1

Time Weighted Average Exposures to Constituents of Welding Fume

Plant 7, Vermeer Manufacturing

1/14/97

Welder	Sample Duration (minutes)		Al	As	Ba	Be	Cd	Co	Cr	Cu	Fe_2O_3 (as Fe)	Mn	Mo	Ni	Pb	Pt	Se	Ag	Te	TiO_2	V_2O_5	ZnO	Zr
A	307	222	11	TR*	14	ND	ND	ND	TR	27	1500	*170*	ND	5 9	ND	ND	5 8**	TR*	ND	ND	ND	15	TR
B	311	211	8 7	TR	15	TR	ND	TR**	TR	20	1500	120	ND	6 5	TR**	ND	ND	ND	ND	ND	ND	7.3	ND
C	308	215	12	TR*	11	TR	ND	TR**	TR	*82*	3200	*509*	ND	4 0	ND	ND	TR*	TR*	ND	ND	ND	13	ND
D	291	232	12	TR	15	TR	ND	TR**	TR	43	2300	*270*	ND	6 0	ND	ND	TR**	ND	ND	ND	ND	13	ND
E	311	219	ND	ND	*8 6*	TR	ND	ND	ND	*8.2*	410	*50*	ND	TR**	ND	ND	ND	ND	ND	ND	TR**	ND	ND
F	286	240	11	TR	17	ND	ND	1 0*	3 1	53	*3500*	*270*	ND	8.2	ND	12*	ND	TR**	ND	ND	ND	13	ND
G	304	216	14	TR	17	TR	ND	TR**	4 0	54	3200	*420*	ND	9 4	ND	ND	TR**	TR**	ND	ND	ND	20	ND
H	307	214	13	TR**	22	ND	ND	TR**	3 2*	60	*3600*	*590*	ND	10	ND	ND	ND	0 34*	TR*	0 97**	TR	40	ND
I	310	215	9 3	TR	24	TR**	ND	0 89*	TR	29	1700	*180*	ND	9 3	2 1**	ND	ND	ND	TR**	ND	ND	8 4	ND
J	304	79	8 0**	TR**	14	ND	ND	0 85**	TR**	36	2300	*290*	ND	5 5	TR**	ND	ND	ND	TR**	ND	ND	15*	TR**
K	285	246	8 6	TR	20	TR	ND	ND	TR	27	1200	130	ND	5 8	ND	ND	TR*	ND	3 1**	ND	ND	7.3	ND
L	294	212	TR**	ND	16	TR	TR**	ND	TR**	50	2100	*200*	TR*	4 1	ND	ND	ND	ND	ND	ND	ND	6 5	TR*
M	300	207	TR**	TR*	8 3	TR	ND	TR	TR	16	710	77	ND	4 7*	2 4**	ND	TR**	ND	ND	ND	ND	4 6*	TR
N	311	212	6 5*	TR**	18	0 057*	ND	0 85**	TR	43	2000	*300*	ND	6 3	ND	TR**	ND	ND	TR	ND	ND	14	ND
O	293	208	TR	ND	16	TR	ND	0 59**	TR	45	1600	*170*	ND	3 9	TR**	ND	ND	ND	ND	ND	ND	9.3	TR**
P	131	200	ND	ND	13	TR	ND	TR	TR	29	1400	110	ND	3 7	TR**	ND	ND	ND	ND	ND	ND	5.2**	ND
Q	288	210	TR**	ND	16	TR	ND	ND	TR	28	980	*190*	ND	3 3	ND	ND	ND	ND	TR	ND	ND	7 1	ND
R	311	175	TR**	ND	17	TR	TR*	TR**	ND	33	1300	*140*	ND	4 5	ND	ND	ND	ND	ND	ND	ND	5 1	ND
NIOSH REL			5000	2 C	none	0 5 Ca	Ca	50	500	100	5000	1000 3000 ST	none	Ca 15	100	1000	200	10	100	Ca	50 C	5000, 10000 ST	5000 10000 ST
Adjusted ACGIH TLV			3500	7 A1	350 A4	1 4 7 ST A1	7* A2	14 A3	350 A4	140	3500 A4	140	7000	700	35 A3	700	140	70	70	7000 A4	35 A4	3500 7000 ST	3500 7000 ST A4
Adjusted OSHA PEL			none	7	350	1 4 3 5 C 18 P	3 5	70	700	70	7000	3500 C	10500	700	40*	none	140	7	70	10500	70 C	3500	3500

No magnesium, thallium, or yttrium were detected in these samples Those results have been omitted from this table for the sake of clarity

Table II

Time Weighted Average Exposures to Constituents of Welding Fume
Plant 7, Vermeer Manufacturing
1/15/97

Welder	Sample Duration (minutes)		Al	Ba	Be	Cd	Co	Cr	Cu	Fe_2O_3 (as Fe)	MgO	Mn	Mo	Ni	Pb	Pt	Ag	Te	TiO_2	V_2O_5	ZnO	Zr
A	296	246	23	7 7	ND	TR**	0 70**	TR	19	990	28	150	ND	2 1	TR**	ND	TR**	TR**	ND	TR**	16	TR**
B	292	252	18	6 9	ND	TR**	TR	ND	16	970	12	120	ND	1 7*	TR**	ND	ND	ND	ND	TR**	6 7	ND
C	289	250	9 1	7.3	ND	TR*	TR	TR**	29	1600	23	270	ND	2 1*	ND	ND	ND	ND	ND	ND	20	0 43*
D	286	256	15	9 1	ND	ND	0 78*	TR	12	780	14	78	ND	3 3	TR**	ND	ND	TR**	ND	ND	6 9	0 59*
E	288	254	13	7 9	TR**	TR	TR	TR	37	2500	20	320	ND	2 7	TR**	ND	TR	TR**	ND	ND	14	TR**
F	289	259	10	7 5	TR**	TR*	TR	2 3*	36	2100	25	200	TR*	3 4	TR	ND	TR**	ND	ND	TR**	9.2	0 89
G	290	257	13	9 7	TR*	TR*	0 84*	2 9*	57	2500	30	380	ND	5 1	TR	TR**	TR**	TR**	ND	ND	18	0 40*
H	293	261	TR	11	TR**	ND	ND	TR**	21	940	9 7	150	TR**	4 1	ND	ND	ND	ND	ND	ND	12	ND
I	287	263	17	13	ND	TR**	TR	TR	16	950	13	110	ND	5 6	TR	ND	TR**	TR**	ND	ND	10	ND
J	296	298	9 7*	9 7	ND	ND	0 75*	TR	30	1800	18	250	ND	2 0	ND	TR**	TR	ND	ND	ND	11	0.37*
K	221	void	10	5 0	TR	TR	TR	ND	19	1100	9 5	170	ND	TR	TR	ND	ND	ND	ND	ND	13	ND
M	307	294	8 2*	10	TR*	ND	TR	TR	42	2100	25	230	ND	2.2	TR	ND	ND	ND	TR**	ND	15	0 55*
N	295	228	9 1	7 9	ND	ND	TR**	TR	25	1400	17	160	ND	1 9*	ND	ND	TR	ND	ND	ND	11	0.36**
O	299	292	7 8*	10	TR**	ND	0 63*	TR	27	1400	15	210	ND	TR	TR**	ND	TR	ND	ND	ND	22	TR
P	310	283	23	11	TR**	ND	TR	5 3	19	1300	33	140	ND	4 0	TR**	ND	TR*	TR**	ND	ND	9 0	TR
Q	302	292	6 9	11	ND	ND	0 57	TR	33	1700	17	240	ND	1 7*	TR*	ND	TR	TR	ND	TR	14	TR
R	301	220	11	12	ND	TR*	TR	TR	26	1400	28	240	ND	TR	ND	ND	TR	ND	1 0**	ND	9 0	TR**
S	297	225	14*	10	ND	ND	0 75*	TR	24	1200	50	160	ND	2 0*	ND	ND	TR	ND	TR**	ND	8 1	ND
NIOSH REL			5000	none	0 5 Ca	Ca	50	500	100	5000	none	1000 3000 ST	none	Ca 15	100	1000	10	100	Ca	50 C	5000, 10000 ST	5000 10000 ST
Adjusted ACGIH TLV			3500	350 A4	1 4 7 ST A1	7* A2	14 A3	350 A4	140	3500 A4	7000	140	7000	700	35 A3	700	70	70	7000 A4	35 A4	3500 7000 ST	3500 7000 ST A4
Adjusted OSHA PEL			none	350	1 4 3 5 C 18 P	3 5	70	700	70	7000	10500	3500 C	10500	700	40#	none	7	70	10500	70 C	3500	3500

No arsenic, selenium, thallium, or yttrium were detected in these samples Those results have been omitted from this table for the sake of clarity

Table III

Time Weighted Average Exposures to Constituents of Welding Fume
Plant 7, Vermeer Manufacturing
1/16/97

Welder	Sample Duration (minutes)		Al	Ba	Be	Cd	Co	Cr	Cu	Fe_2O_3 (as Fe)	MgO	Mn	Mo	Ni	Pb	Ag	Te	TiO_2	V_2O_5	ZnO	Zr
A	341	186	14	3 9	ND	Nd	TR*	TR	23	1400	12	*190*	ND	TR	TR	ND	ND	ND	ND	19	0 47*
B	337	189	6 4*	4 2	ND	ND	ND	TR	9 9	530	20	62	TR*	TR**	ND	ND	ND	ND	ND	4 9	ND
D	343	191	9 2	3 1	ND	ND	TR*	TR*	8 9	560	20	54	ND	1 8	ND	ND	TR*	ND	ND	4 8	ND
E	343	187	13	4 2	ND	ND	TR	TR	12	770	25	88	ND	TR**	ND	TR	ND	ND	ND	6 1	TR
F	324	210	13	5 6	TR**	ND	TR**	TR	42	2400	25	*300*	ND	2 8	ND	TR**	ND	ND	ND	16	TR
G	349	189	*18*	5 9	TR**	*ND*	*0 71**	*3.3**	*40*	*2200*	*30*	*230*	ND	4 5	*ND*	TR**	ND	TR**	ND	14	TR
H	349	189	10	7 0	ND	TR**	TR	3 6*	30	2000	25	*200*	ND	5 4	TR	TR**	TR**	ND	ND	15	TR**
I	348	188	10	9 1	ND	ND	TR	TR	14	830	23	81	ND	4.2	TR**	TR**	ND	ND	ND	10	ND
J	339	187	9 0	3 2	ND	ND	ND	TR	16	804	20	110	ND	TR**	ND	ND	ND	ND	ND	7 4	0.38**
K	320	202	7 2*	3 5	TR*	ND	TR**	TR	22	1200	37	*160*	ND	TR	ND	TR**	ND	ND	ND	12	ND
L	340	184	9 4*	3 7	ND	ND	TR	TR	24	1400	23	*140*	ND	TR	ND	ND	TR**	ND	TR*	6 9	TR**
M	334	179	8 0*	3 4	ND	ND	TR	TR	43	2100	32	*230*	ND	TR	TR**	TR**	ND	ND	ND	14	0 65*
N	330	183	TR**	3 0	ND	ND	ND	TR	17	880	30	96	1 1*	ND	ND	ND	TR**	ND	ND	6 1*	ND
O	321	187	TR	3 3	ND	ND	ND	TR	21	1000	30	*150*	TR**	TR**	ND	ND	TR**	ND	ND	15	ND
P	324	178	9 4	3 6	ND	ND	TR**	TR	17	970	32	99	ND	TR	ND	ND	ND	ND	ND	7 8	TR**
Q	321	194	5 7*	3 2	ND	ND	ND	TR	29	1300	17	*190*	1 6*	TR*	ND	ND	ND	ND	ND	10	ND
R	321	182	12*	3 9	TR**	ND	TR**	TR	32	1700	22	*290*	TR**	ND	TR*	TR*	ND	ND	TR	13	TR**
S	348	156	TR**	3 6	ND	ND	ND	TR**	11	540	30	67	TR**	[illegible]	ND	ND	ND	ND	ND	5 0*	ND
NIOSH REL			*5000*	none	*0 5 Ca*	*Ca*	*50*	*500*	*100*	5000	*none*	1000 3000 ST	*none*	Ca 15	100	10	100	Ca	50 C	5000 10000 ST	5000 10000 ST
Adjusted ACGIH TLV			3500	350 A4	1 4 7 ST A1	7* A2	14 A3	350 A4	140	3500 A4	7000	140	7000	700	35 A3	70	70	7000 A4	35 A4	3500 7000 ST	3500 7000 ST A4
Adjusted OSHA PEL			none	350	1 4 3 5 C 18 P	3 5	70	700	70	7000	10500	3500 C	10500	700	40*	7	70	10500	70 C	3500	3500

No arsenic, platinum, selenium, thallium, or yttrium were detected in these samples Those results have been omitted from this table for the sake of clarity

Table IV
Time Weighted Average Exposures to Constituents of Welding Fume
Plant 4, Vermeer Manufacturing
1/14/97

Welder	Sample Duration (minutes)		Al	Ba	Cd	Cr	Cu	Fe_2O_3 (as Fe)	MgO	Mn	Mo	Ni	Pb	Ag	Te	V_2O_5	ZnO	Zr
AA	104	263	5 3	TR	ND	TR	35	2000	35	*280*	2 6*	TR**	ND	ND	ND	TR**	12	TR
BB	247	280	4 0	TR	ND	TR	39	2200	27	*270*	TR	TR**	ND	TR**	TR**	ND	25	ND
CC	256	261	3 7	TR	ND	TR	31	1700	28	*290*	ND	TR**	TR**	TR**	ND	ND	15	ND
X	256	262	8 3	TR	ND	TR	26	1500	27	*180*	TR**	ND	ND	ND	ND	TR**	7 4	ND
Y	242	269	12	TR	ND	TR	51	3100	35	*410*	1 2**	TR	TR**	TR	ND	ND	12	ND
Z	243	264	4 9	TR	TR**	TR	28	1600	23	*250*	ND	TR**	TR**	TR**	ND	ND	11	ND
NIOSH REL			5000	none	Ca	500	100	5000	none	1000 3000 ST	none	Ca 15	100	10	100	50 C	5000, 10000 ST	5000 10000 ST
Adjusted ACGIH TLV			3500	350 A4	7* A2	350 A4	140	3500 A4	7000	140	7000	700	35 A3	70	70	35 A4	3500 7000 ST	3500 7000 ST A4
Adjusted OSHA PEL			none	350	3 5	700	70	7000	10500	3500 C	10500	700	40#	7	70	70 C	3500	3500

No arsenic, beryllium, cobalt, platinum, selenium, tellurium, thallium, titanium, or yttrium were detected in these samples   Those results have been omitted from this table for the sake of clarity

Table V
Time Weighted Average Exposures to Constituents of Welding Fume
Plant 4, Vermeer Manufacturing
1/15/97

Welder	Sample Duration (minutes)		Al	Ba	Cd	Co	Cr	Cu	Fe_2O_3 (as Fe)	MgO	Mn	Mo	Ni	Pb	Pt	Se	Ag	V_2O_5	ZnO	Zr
AA	285	174	TR**	TR	ND	ND	TR	52	*3500*	33	*340*	ND	TR	TR**	ND	ND	TR	ND	25	TR**
BB	261	214	ND	TR**	ND	ND	TR	22	1400	17**	*190*	ND	ND	TR**	TR**	ND	ND	ND	11	ND
CC	255	199	TR**	TR	ND	TR**	3 4*	20	1500	17	*170*	ND	1 6**	TR**	ND	ND	ND	ND	13	0 29**
X	257	219	ND	TR**	TR	TR**	TR**	8 7	540	17**	79	TR**	ND	TR**	ND	ND	ND	ND	5 5	ND
Y	254	215	TR	TR	ND	ND	TR	30	1700	33	*280*	TR	ND	TR	TR**	ND	TR**	TR**	11	ND
Z	256	217	7 8*	TR	TR**	ND	TR	36	2300	22	*330*	ND	ND	TR**	ND	ND	ND	ND	11	ND
NIOSH REL			5000	none	Ca	50	500	100	5000	none	1000 3000 ST	none	Ca 15	100	1000	200	10	50 C	5000, 10000 ST	5000 10000 ST
Adjusted ACGIH TLV			3500	350 A4	7[a] A2	14 A3	350 A4	140	3500 A4	7000	140	7000	700	35 A3	700	140	70	35 A4	3500 7000 ST	3500 7000 ST A4
Adjusted OSHA PEL			none	350	3 5	70	700	70	7000	10500	3500 C	10500	700	40#	none	140	7	70 C	3500	3500

No arsenic, beryllium, selenium, tellurium, thallium, titanium, or yttrium were detected in these samples Those results have been omitted from this table for the sake of clarity

Table VI

Time Weighted Average Exposures to Constituents of Welding Fume

Plant 4, Vermeer Manufacturing

1/16/97

Welder	Sample Duration (minutes)		Al	Ba	Cd	Co	Cr	Cu	Fe_2O_3 (as Fe)	MgO	Mn	Mo	Ni	Pb	Ag	TiO_2	ZnO	Zr
AA	253	258	11	0 60	TR**	ND	TR	30	2100	17**	270	ND	ND	TR	TR**	ND	11	TR
BB	254	256	14	TR	TR**	ND	TR	31	2100	25	180	0 81**	TR	TR	ND	ND	21	ND
CC	253	258	14	TR**	ND	ND	TR	25	1800	8 5**	270	ND	ND	TR	ND	TR**	11	TR**
X	254	251	11	TR	ND	TR**	TR**	10	590	23	94	ND	ND	TR	ND	ND	7 5	ND
Y	251	255	12	0 39*	ND	ND	TR	27	1700	43	290	ND	ND	TR	TR**	ND	11	ND
Z	252	264	14	TR**	ND	TR**	TR	33	2300	11**	270	ND	TR**	TR	ND	27**	9 6	ND
NIOSH REL			5000	none	Ca	50	500	100	5000	none	1000 3000 ST	none	Ca 15	100	10	Ca	5000, 10000 ST	5000 10000 ST
Adjusted ACGIH TLV			3500	350 A4	7* A2	14 A3	350 A4	140	3500 A4	7000	140	7000	700	35 A3	70	7000 A4	3500 7000 ST	3500 7000 ST A4
Adjusted OSHA PEL			none	350	3 5	70	700	70	7000	10500	3500 C	10500	700	40†	7	10500	3500	3500

No arsenic, beryllium, platinum, selenium, tellurium, thallium, vanadium, or yttrium were detected in these samples Those results have been omitted from this table for the sake of clarity

Table VII
Time Weighted Average Exposures to Constituents of Welding Fume
Plant 1, Vermeer Manufacturing
1/14/97

Welder	Sample Duration (minutes)		Al	Ba	Cr	Cu	Fe_2O_3 (as Fe)	MgO	Mn	Mo	Ni	Pt	Ag	TiO_2	ZnO	Zr
T	259	233	9 1	TR	ND	18	990	18	*140*	ND	ND	ND	ND	ND	6 6	ND
U	197	306	13	0 34*	TR	55	3200	20	*460*	1 7*	ND	TR	TR	2 5**	32	ND
V	266	259	9 4	0 34*	TR	45	2300	18	*300*	TR	TR	ND	TR	ND	25	ND
W	261	257	5 2*	TR	TR	30	1500	27	*150*	TR	TR	ND	ND	ND	10	TR
NIOSH REL			5000	none	500	100	5000	none	1000 3000 ST	none	Ca 15	1000	10	Ca	5000, 10000 ST	5000 10000 ST
Adjusted ACGIH TLV			3500	350 A4	350 A4	140	3500 A4	7000	140	7000	700	700	70	7000 A4	3500 7000 ST	3500 7000 ST A4
Adjusted OSHA PEL			none	350	700	70	7000	10500	3500 C	10500	700	none	7	10500	3500	3500

No arsenic, beryllium, cadmium, cobalt, lead, selenium, tellurium, thallium, vanadium, or yttrium were detected in these samples Those results have been omitted from this table for the sake of clarity

Table VIII
Time Weighted Average Exposures to Constituents of Welding Fume
Plant 1, Vermeer Manufacturing
1/15/97

Welder	Sample Duration (minutes)		Al	Ba	Cd	Co	Cr	Cu	Fe_2O_3 (as Fe)	MgO	Mn	Mo	Ni	Pb	Pt	Ag	TiO_2	V_2O_5	ZnO
T	243	298	11*	0 44*	TR**	ND	TR	23	1400	22	*180*	TR**	TR**	TR	ND	ND	2 0**	ND	8 0
U	240	293	4 9**	0 32**	ND	ND	TR**	38	2300	18**	*320*	TR**	TR	TR	ND	TR**	ND	ND	30
V	243	294	TR	TR	ND	TR**	TR**	39	2400	ND	*280*	ND	1 5**	ND	TR**	ND	1 2**	ND	23
W	228	294	TR	TR	ND	TR	TR**	25	1500	15**	*190*	TR**	TR**	ND	ND	TR**	ND	TR**	16
NIOSH REL			5000	none	Ca	50	500	100	5000	none	1000 3000 ST	none	Ca 15	100	1000	10	Ca	50 C	5000 10000 ST
Adjusted ACGIH TLV			3500	350 A4	7[a] A2	14 A3	350 A4	140	3500 A4	7000	140	7000	700	35 A3	700	70	7000 A4	35 A4	3500 7000 ST
Adjusted OSHA PEL			none	350	3 5	70	700	70	7000	10500	3500 C	10500	700	40[f]	none	7	10500	70 C	3500

No arsenic, beryllium, selenium, tellurium, thallium, yttrium, or zirconium were detected in these samples Those results have been omitted from this table for the sake of clarity

Table IX
Time Weighted Average Exposures to Constituents of Welding Fume
Plant 1, Vermeer Manufacturing
1/16/97

Welder	Sample Duration (minutes)		Al	As	Ba	Be	Cd	Cr	Cu	Fe_2O_3 (as Fe)	MgO	Mn	Mo	Ni	Pb	Pt	Ag	TiO_2	ZnO	Zr
T	244	269	8 2	ND	0 25''	ND	TR''	TR''	18	960	17''	120	TR	ND	TR''	ND	ND	ND	6 5	ND
U	240	270	16	TR''	0 52	ND	ND	TR	42	2500	23	330	ND	TR''	TR''	TR''	ND	ND	27	ND
V	244	267	11	ND	0 41'	TR''	ND	TR	49	2900	15''	320	ND	TR	TR	ND	TR''	ND	26	TR''
W	243	269	14	ND	0 27'	ND	ND	TR	53	3100	62''	320	ND	TR	TR	ND	TR''	1 5	24	TR''
NIOSH REL			5000	2 C	none	0 5 Ca	Ca	500	100	5000	none	1000 3000 ST	none	Ca 15	100	1000	10	Ca	5000, 10000 ST	5000 10000 ST
Adjusted ACGIH TLV			3500	7 A1	350 A4	1 4 7 ST A1	7ª A2	350 A4	140	3500 A4	7000	140	7000	700	35 A3	700	70	7000 A4	3500 7000 ST	3500 7000 ST A4
Adjusted OSHA PEL			none	7	350	1 4 3 5 C 18 P	3 5	700	70	7000	10500	3500 C	10500	700	40'	none	7	10500	3500	3500

No cobalt, selenium, tellurium, thallium, vanadium, or yttrium were detected in these samples Those results have been omitted from this table for the sake of clarity

Notes to Tables I-IX

1) Samples were collected at a flow rate of 2 liters per minute
2) Unless otherwise noted, units are in micrograms of analyte per cubic meter of sampled air
3) Results are reported to two significant digits
4) Where separate exposure limits have been established for the dust and fume of the metals listed above, the exposure limit for the fume is presented
5) TWAs are presented as actual TWAs, assuming exposure from the sampled period represents exposure during the remainder of the 10-hour workday To convert to a 10-hour TWA assuming zero exposure for the unsampled period, multiply the result by the total sampling time (the value in the second column plus the value in the third column) and divide the product by 600 minutes
6) For metals in the first row, given as oxides of the elemental analytes (Fe_2O_3 for Fe, MgO for Mg, TiO_2 for Ti, V_2O_5 for V, and ZnO for Zn) for comparison with occupational exposure limits, it was assumed that oxides of these metals would be common when the metals were heated in the presence of air during welding However, a separate, specific test, such as X-ray diffraction, or a differential solubility separation, can be done on a case by case basis to prove the presence of oxides In order to convert from the reported result as the elemental analyte to the oxide, the result was multiplied by the ratio of the molecular weight of the compound to the atomic weight of the elemental analyte (in grams per mole), e g , 1 25 to convert from Zn to ZnO
7) **ND** (not detected) the results were less than the limit of detection of the method (see Table X)
8) **TR** (trace) the result was less than the limit of quantitation, but above the limit of detection of the method, and there is limited confidence in its accuracy (see Table X)
9) * one of the two sample results used to calculate the time weighted average (TWA) was a trace value
10) **: one of the two sample results used to calculate the TWA was less than the limit of detection (LOD) A value of the LOD/√2 was used in its place to calculate the TWA
11) **C** (ceiling limit) a value which is not to be exceeded at any time during the work day
12) **Ca.** the substance is considered a potential occupational carcinogen by NIOSH, in accordance with the OSHA classification outlined in 29 CFR 1990 103, and that occupational exposures should be limited to the lowest feasible concentration
13) **ST** short term exposure limit
14) α the TLV is for the inhalable fraction, the samplers used in this evaluation measure total particulate They are not directly comparable, but are nearly equivalent for particles in the size range of welding fumes for the samplers used in this investigation
15) # the PEL for lead is adjusted using the formula in the OSHA lead standard (29CFR1910 1025(c)(2)) Maximum permissible limit (in μg/m³) = 400 ÷ hours worked in the day
16) **P** (peak exposure limit) for beryllium, an employee may be exposed to a concentration above 3 5 μg/m³ (but never above 18 μg/m³) only for a maximum period of 30 minutes Such exposures must be compensated by exposures below the TWA PEL of 1 4 μg/m³, so that the cumulative exposures for the work shift do not exceed 1 4 μg/m³ These numbers reflect a PEL adjusted for a 10-hour workday
17) **A1** ACGIH has classified this substance as a confirmed human carcinogen
18) **A2** ACGIH has classified this substance as a suspected human carcinogen
19) **A3** ACGIH has classified this substance as an animal carcinogen, but available evidence suggests that the substance is not likely to cause cancer in humans except under uncommon or unlikely routes or levels of exposure
20) **A4** ACGIH has determined that this substance is not classifiable as a human carcinogen there are inadequate data on which to make a classification in terms of its carcinogenicity in humans and or

animals

21) **NIOSH REL** exposure limit recommended by the National Institute for Occupational Safety and Health

22) **Adjusted OSHA PEL** permissible exposure limit mandated by the Occupational Safety and Health Administration, adjusted for a 10-hour workday

23) **Adjusted ACGIH® TLV®** threshold limit value recommended by the American Conference of Governmental Industrial Hygienists, adjusted for a 10-hour workday

24) For arsenic (As), the LOD is 3 µg/filter, and the LOQ is 7 5 µg/filter The maximum sample volume for this study was 0 698 m^3, which equates to a minimum detectable concentration (LOD/maximum sample volume) of 4 µg/m^3, and a minimum quantifiable concentration (LOQ/maximum sample volume) of 11 µg/m^3, thus the NIOSH REL of 2 µg/m^3 as a ceiling value is less than the minimum detectable concentration Therefore, any detectable amount of As would result in an exposure above that ceiling Furthermore, both the adjusted ACGIH TLV-TWA and adjusted OSHA PEL-TWA of 7µg/m^3 lie in the range of uncertainty between the minimum detectable concentration and the minimum quantifiable concentration The data in this range are reported as trace values (with limited confidence in its accuracy) in these tables Caution should be used in interpreting these results

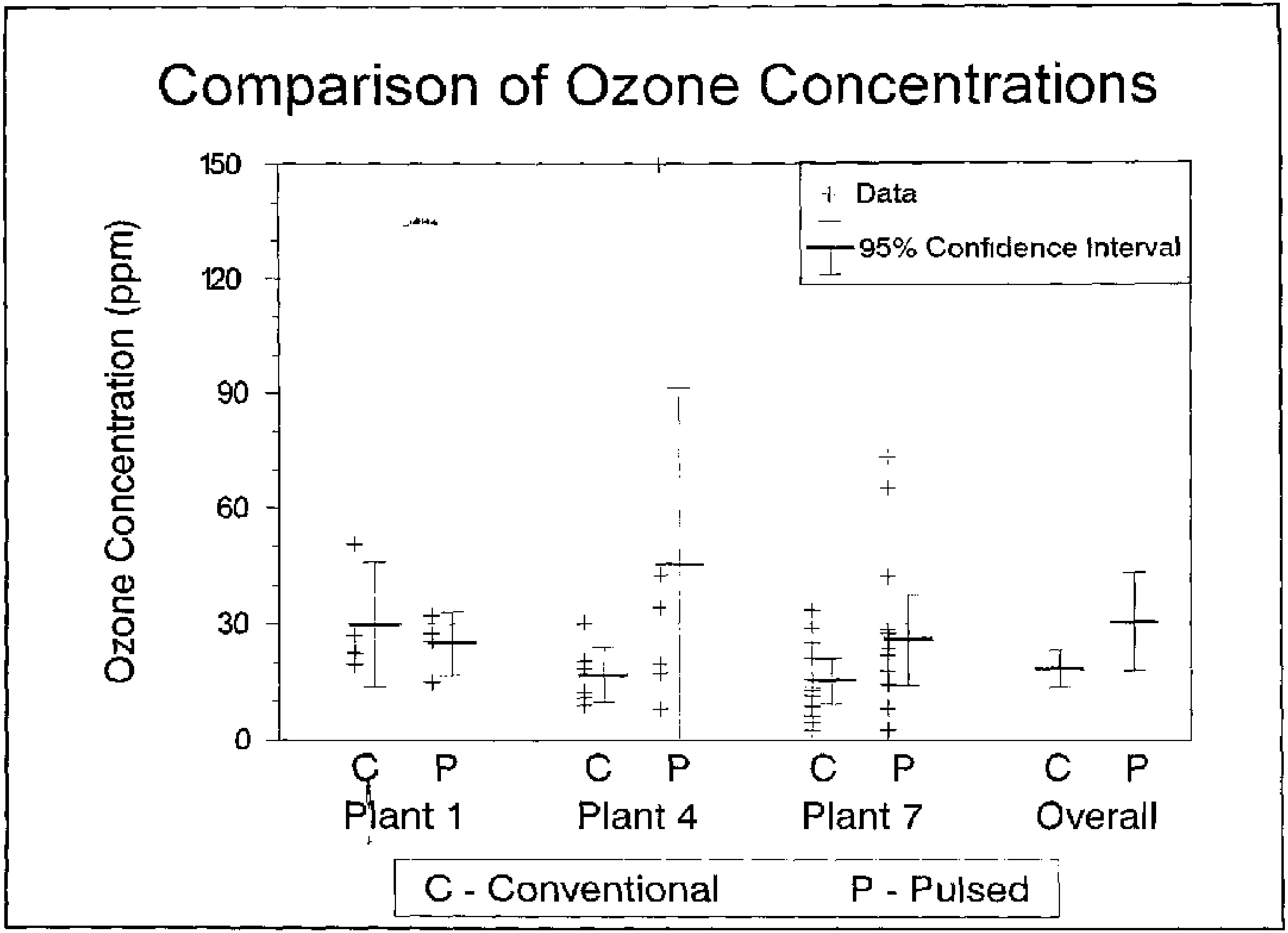
Table X
Limits of Detection and Quantitation for Constituents of Welding Fume
Vermeer Manufacturing
January 14-16, 1997

Analyte (Atomic Symbol)	Limit of Detection (µg/filter)	Limit of Quantitation (µg/filter)
Aluminum (Al)	1	3.5
Arsenic (As)	3	7.5
Barium (Ba)	0.05	0.17
Beryllium (Be)	0.01	0.035
Cadmium (Cd)	0.08	0.25
Cobalt (Co)	0.2	0.43
Chromium(Cr)	0.5	1.7
Copper (Cu)	0.08	0.25
Iron (Fe)	0.8	2.5
Magnesium (Mg)	0.5	1.7
Manganese (Mn)	0.01	0.035
Molybdenum (Mo)	0.3	0.85
Nickel (Ni)	0.5	1.0
Lead (Pb)	0.5	1.7
Platinum (Pt)	3	7.5
Selenium (Se)	2	4.3
Silver (Ag)	0.08	0.25
Tellurium (Te)	0.8	2.5
Thallium (Tl)	3	7.5
Titanium (Ti)	0.2	0.43
Vanadium (V)	0.08	0.25
Yttrium (Y)	0.02	0.043
Zinc (Zn)	0.5	1.7
Zirconium (Zr)	0.08	0.25

µg means micrograms, 1/1000 of a gram
LOD is given as 1 significant digit, LOQ is given as 2 significant digits

Appendix D Blank-Corrected Ozone Data

Sampler #	Welding	Person	Date	Plant	Start Time	Stop Time	Total Time	Conc (ppb)	Conc (ppm)
1	P	E	14-Jan	7	6 00 AM	2 59 PM	8 59	8 3	0 01
2	P	B	14-Jan	7	6 00 AM	11 40 AM	29 40	2 8	0 00
3	P	J	14-Jan	7	6 01 AM	2 47 PM	8 46	21 7	0 02
4	C	A	14-Jan	7	6 01 AM	3 01 PM	9 00	21	0 02
5	C	C	14-Jan	7	6 02 AM	2 56 PM	8 54	12 8	0 01
6	C	I	14-Jan	7	6 02 AM	2 59 PM	8 57	4 7	0 00
7	P	G	14-Jan	7	6 03 AM	2 54 PM	8 51	73 1	0 07
8	C	H	14-Jan	7	6 03 AM	2 55 PM	8 52	28 7	0 03
9	P	F	14-Jan	7	6 04 AM	3 00 PM	8 56	65	0 07
10	C	D	14-Jan	7	6 04 AM	2 58 PM	8 54	2 5	0 00
11	C	K	14-Jan	7	6 05 AM	3 06 PM	9 01	6 2	0 01
12	P	M	14-Jan	7	6 05 AM	2 42 PM	8 37	27 2	0 03
13	P	N	14-Jan	7	6 06 AM	3 06 PM	9 00	42	0 04
14	P	S	14-Jan	7	6 07 AM	2 26 PM	8 19	14 3	0 01
15	C	R	14-Jan	7	6 07 AM	2 22 PM	8 15	24 9	0 02
16	P	Q	14-Jan	7	6 08 AM	2 36 PM	8 28	28 2	0 03
17	C	O	14-Jan	7	6 09 AM	2 39 PM	8 30	11 4	0 01
18	C	P	14-Jan	7	6 09 AM	2 31 PM	8 22	33 5	0 03
19	P	L	14-Jan	7	6 10 AM	2 45 PM	8 35	8 1	0 01
W1	C	L	15-Jan	7	6 45 AM	2 59 PM	8 14	8 8	0 01
W2	P	H	15-Jan	7	6 48 AM	3 02 PM	8 14	17 7	0 02
W3	C	M	15-Jan	7	6 50 AM	3 52 PM	9 02	15 5	0 02
W4	C	N	15-Jan	7	6 04 AM	2 48 PM	8 44	13 6	0 01
W5	P	C	15-Jan	7	6 26 AM	2 56 PM	8 30	23 5	0 02
W6	P	D	15-Jan	7	6 22 AM	2 59 PM	8 37	2 4	0 00
W8	P	I	15-Jan	7	5 52 AM	3 04 PM	9 12	27 3	0 03
7845	C	BB	14-Jan	4	6 45 AM	3 10 PM	8 25	10 8	0 01
7853	P	AA	14-Jan	4	7 00 AM	3 10 PM	8 10	149 8	0 15
7854	C	Y	14-Jan	4	7 01 AM	3 06 PM	8 05	18 4	0 02
7832	C	X	14-Jan	4	7 04 AM	3 15 PM	8 11	20 3	0 02
7831	P	CC	14-Jan	4	6 55 AM	3 00 PM	8 05	42 6	0 04
7846	P	Z	14-Jan	4	7 07 AM	3 07 PM	8 00	34 1	0 03
7841	P	V	14-Jan	1	6 00 AM	2 14 PM	8 14	32	0 03
7860	C	W	14-Jan	1	6 04 AM	2 12 PM	8 08	28 9	0 03
7848	P	T	14-Jan	1	6 13 AM	2 13 PM	8 00	14 8	0 01
7840	C	U	14-Jan	1	6 18 AM	2 16 PM	7 58	19 5	0 02
115A	C	AA	15-Jan	4	6 49 AM	2 29 PM	7 40	8 9	0 01
115B	C	CC	15-Jan	4	6 58 AM	2 32 PM	7 34	12 4	0 01
115C	P	BB	15-Jan	4	6 47 AM	2 41 PM	7 54	17 3	0 02
115D	P	Y	15-Jan	4	7 03 AM	2 51 PM	7 48	19 7	0 02
115E	C	T	15-Jan	1	6 14 AM	3 16 PM	9 02	50 8	0 05
115F	P	U	15-Jan	1	6 20 AM	3 14 PM	8 54	27 4	0 03
115G	C	Z	15-Jan	4	6 54 AM	2 47 PM	7 53	30 1	0 03
115H	P	W	15-Jan	1	6 25 AM	3 08 PM	8 43	25 3	0 03
115I	P	X	15-Jan	4	6 40 AM	2 37 PM	7 57	8	0 01
115J	C	V	15-Jan	1	6 06 AM	3 04 PM	8 58	22 2	0 02



Comparison of Ozone Concentrations
Ozone Concentration (ppm)
150
120
90
60
30
0
Data
95% Confidence Interval
C
P
Plant 1
C
P
Plant 4
C
P
Plant 7
C
P
Overall
C - Conventional
P - Pulsed

Appendix E Relative Concentration Data as Measured by the Aerosol Photometer

NOTES

1) All data were collected on one welder in Plant 7 on Jan 15-16, 1997
2) Ham operated at 2 lpm, set at 1 second averaging time (sample rate of 4/sec)
3) Ham scale set at 0-20 mg/m^3 (1 volt = 10 mg/m^3)
4) Met One data total count over 10 seconds, then 1 second hold time
4) Met One data only taken on Jan-16 during the pulsed/conventional sample (sampling data from 1/15 could not be retrieved from the instrument)

Jan-15 (welding on subassembly for gear boxes - figure 8 shaped parts)

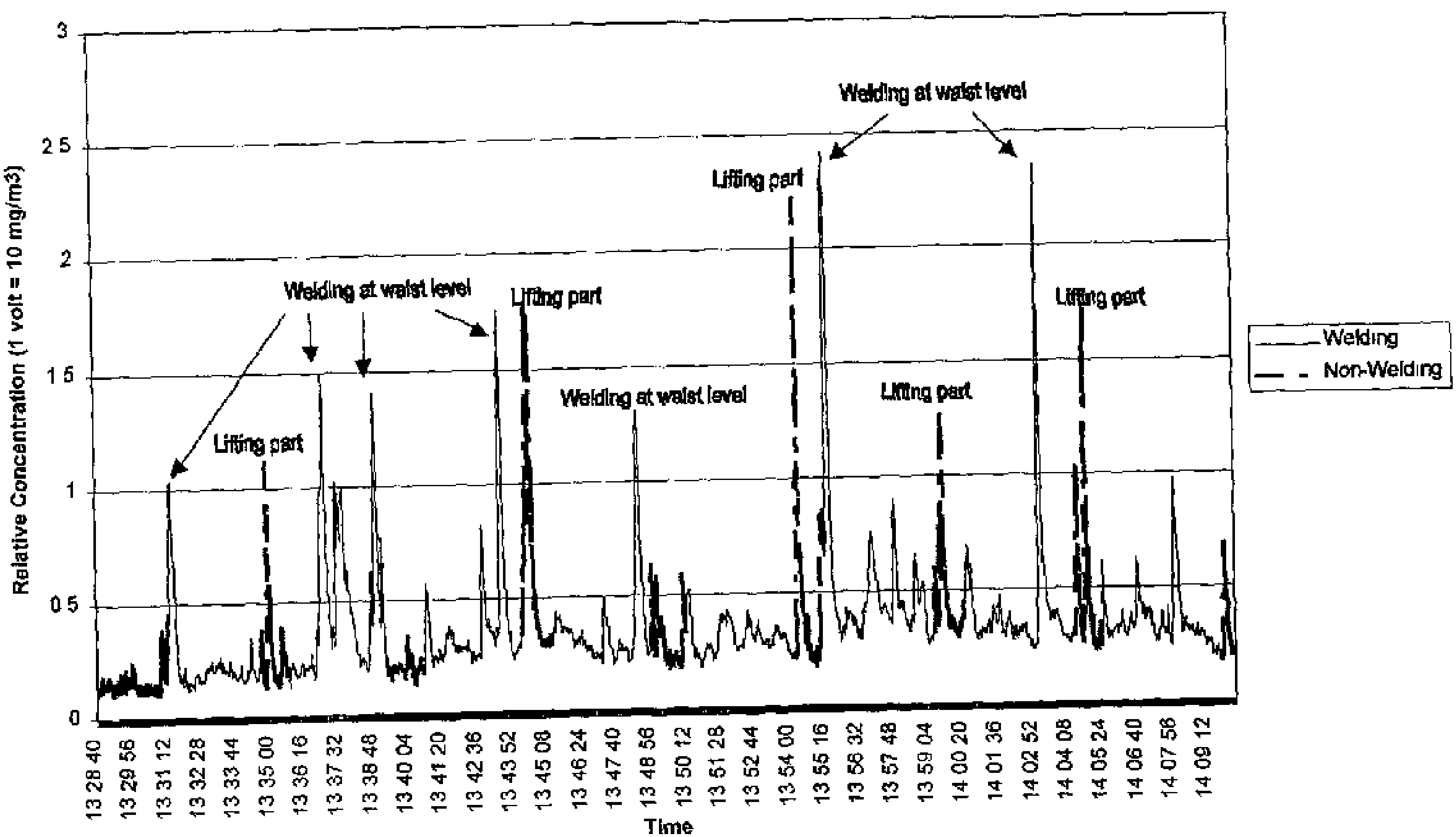
Pulsed.

- Total Time on Pump = 41 min
- Arc Time = ~0 51 hrs
- Filter = #7655
- Welding Parameters
  - Wire Feed = 385 ipm
  - Voltage = 26 5 v
  - Amperage = 255 a
  - Trim = 80
  - Base Metal Thickness = 1/2" - 1 1/4"
  - Wire Diam = 0 045"
  - Wire Type = Lincolnweld L-50
  - Welding Machine = Miller Maxtron 450 cc/cv DC inverter arc welder
  - Electrode Positive
  - Rated Output = 38v, 450a, 100% duty cycle, max ocv = 80
- Completed 8 assemblies
- Temp = 76 F
- Air currents in area = 17 fpm (no fan)

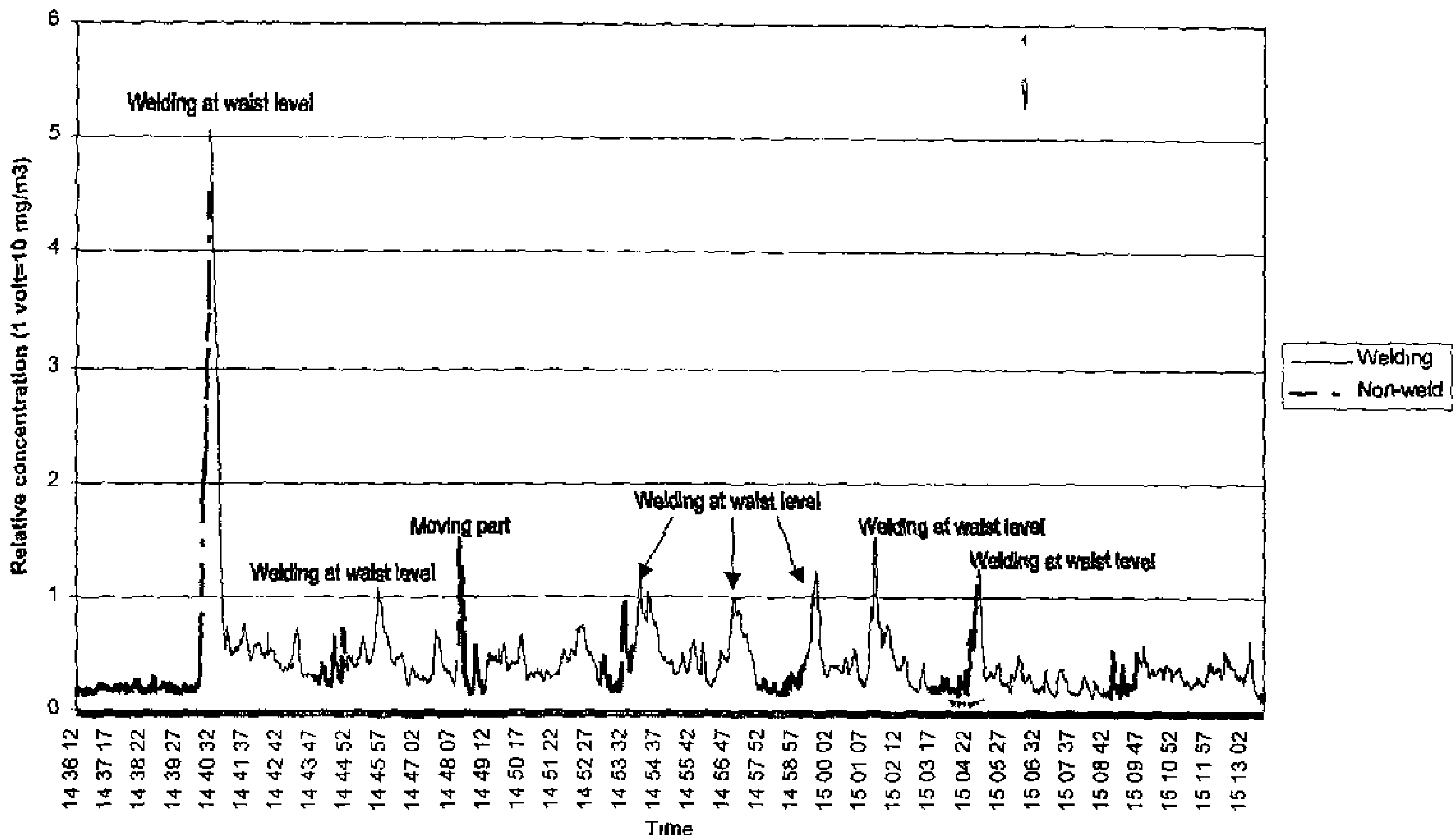
Conventional

- Total Time on Pump = 39 min
- Arc Time = 0 44
- Filter = #7705
- Same Parameters as above, except
  - Voltage = 26 4 v
  - Amperage = 260
- Completed 8 assemblies

Pulsed Welding 1/15/97



Conventional welding 1/15/97



Jan-16 (welding on a gearbox)

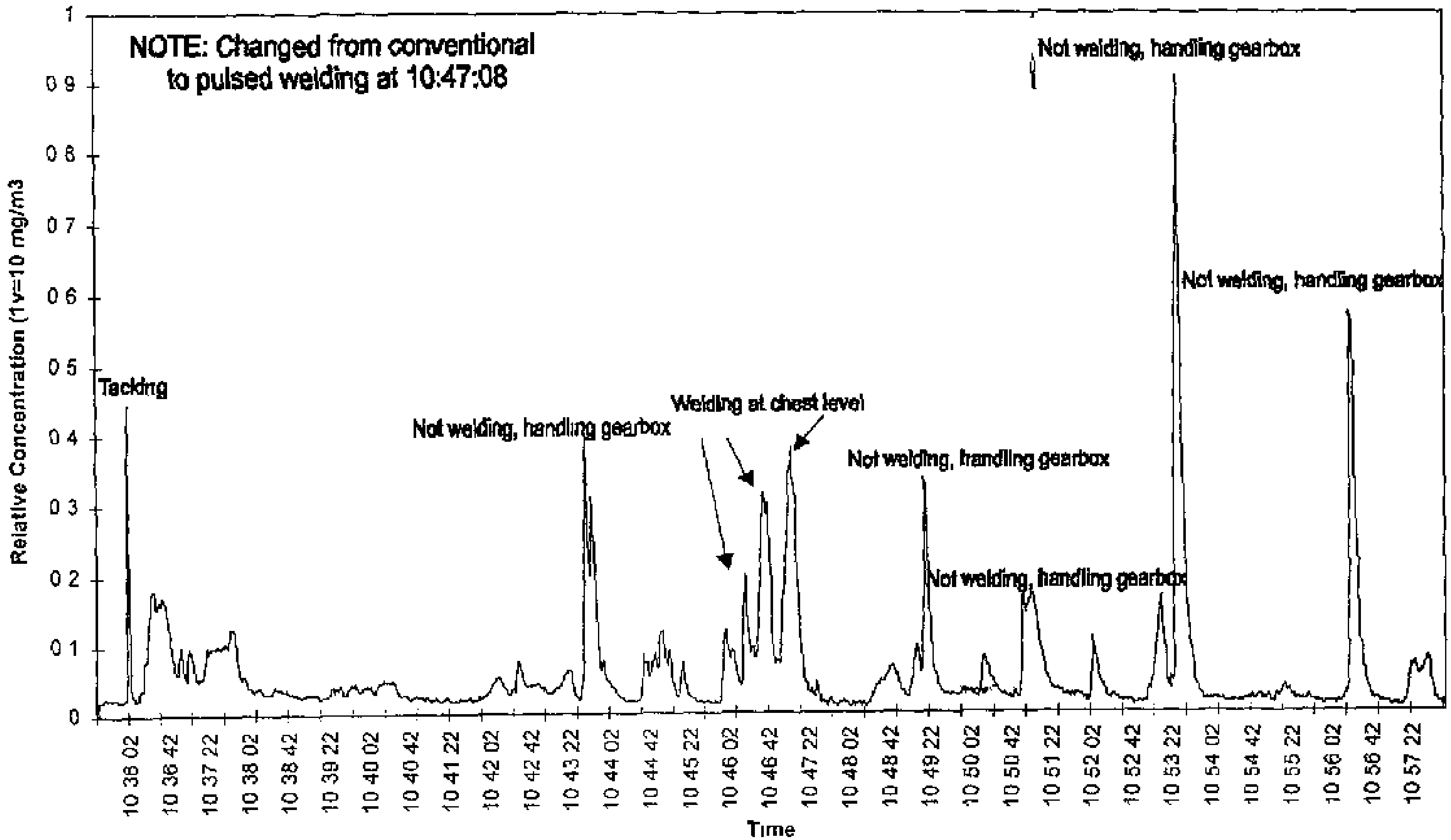
Conventional

Total Time on Pump = 12 min
Arc Time = 0 12 (432 seconds)
Filter = #7664 (conc=0 063 mg/m^3)
Welding Parameters
- Wire Feed = 375 ipm
- Voltage = 27 v
- Amperage = 250 a
- Trim = ?
- Base Metal Thickness = ?
- Wire Diam = 0 045"
- Wire Type = Lincolnweld L-50
- Welding Machine = Miller Maxtron 450 cc/cv DC inverter arc welder
- Electrode Positive
- Rated Output = 38v, 450a, 100% duty cycle, max ocv = 80

Pulsed

Total Time on Pump 10 min
Arc Time = 0 11 hrs (396 seconds)
Filter = #7595 (conc = 0 054 mg/m^3)
Same Parameters as above, except
- Wire Feed = 385 ipm
- Amperage = 235 a
- Trim = 80

Vermeer HAM Data -Conv&Pulsed 1/16 (offset by 0 04)



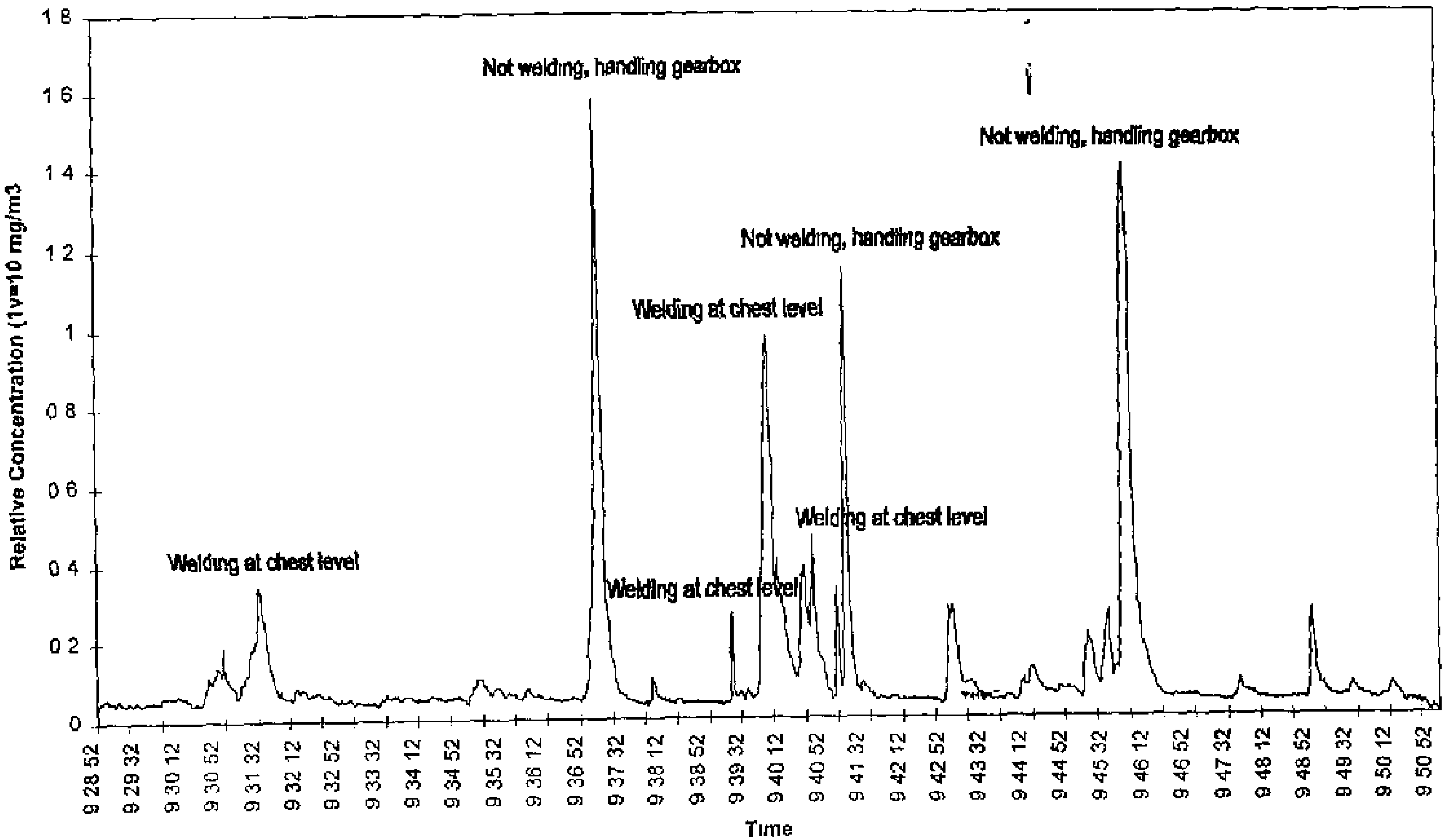
Jan-16 (welding on a gearbox - this data was not included in the analysis since conventional welding data was not obtained and no comparisons could be made)

Pulsed

Total Time on Pump 21 min
Arc Time = 0 23 hrs
Filter = #7666
Welding Parameters
- Wire Feed = 385 ipm
- Voltage = 27 v
- Amperage = 240 a
- Trim = 80
- Base Metal Thickness =
- Wire Diam = 0 045"
- Wire Type = Lincolnweld L-50
- Welding Machine = Miller Maxtron 450 cc/cv DC inverter arc welder
- Electrode Positive
- Rated Output = 38v, 450a, 100% duty cycle, max ocv = 80

Worked on 1 gear box
Temp = 77 2 F
Air currents in area = 30 fpm (no fan)

Vermeer HAM Data = Pulsed 1/16 (offset)



Appendix F Particle Count Data as Measured by the Met One Instrument

Met One Data - 1/16/97 Vermeer Mfg - Pella, Iowa
Conventional data from beginning of file til about 10 48
Pulsed data from about 10 48 until end of file
Arc time = 0 12 for conv, arc time=0 11 for pulsed
Arctimer restarted @ ~10 48 06 for pulsed sample
Conv filter # = 7664,pulsed filter # = 7594

Time	# Particles > 0 3um	# Particles > 3 0um	
103542	111004	391	Filter sample begun @ 10 35 12
103554	112432	380	Datalogger begun @ 10 35 25
103605	111669	340	
103616	127815	507	
103628	133724	640	
103639	144876	1256	
103651	132584	1235	
103703	127213	1303	
103714	130003	560	
103725	134082	513	
103737	136180	453	
103748	135352	490	
103759	126503	462	
103812	125920	543	
103823	118469	556	
103835	119859	454	
103846	118887	487	
103857	117214	462	
103909	115308	482	
103920	115449	538	
103931	116788	446	
103944	136672	509	
103955	133365	612	
104006	126184	446	
104018	134818	332	
104029	128961	355	
104041	120626	342	
104052	117249	406	
104104	111485	414	
104116	109590	373	
104127	109833	375	
104138	113425	323	
104150	120340	317	
104201	129763	410	
104212	122601	325	
104224	117542	349	
104236	121143	372	
104247	124939	400	
104259	119026	338	
104310	124553	353	
104321	126780	358	
104333	119749	1006	

104344	126329	657
104356	118580	354
104408	116353	339
104419	115964	316
104431	123712	4484
104442	128216	4171
104453	136590	1047
104505	123007	415
104516	124130	388
104528	115832	316
104540	115728	260
104551	121729	398
104602	137629	857
104614	125301	620
104625	135285	774
104636	125509	621
104648	129818	374
104700	125406	1248
104711	124211	640
104723	110542	346
104734	110070	318
104746	110885	317
104757	109768	298

	# Particles	# Sample Counts
C-0 3Avg=	122932	65
C-3Avg=	627	

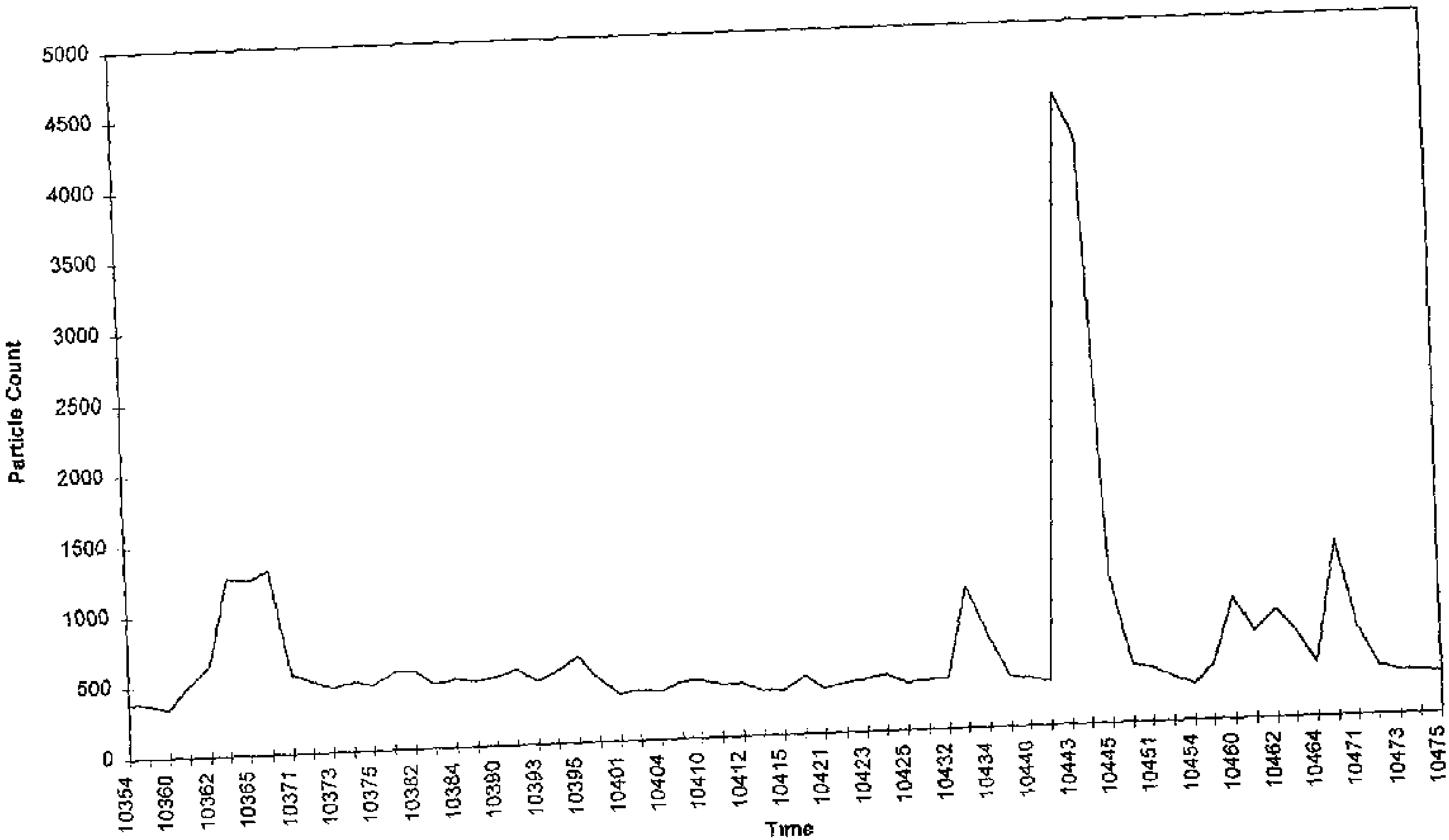
104808	108771	321
104820	114953	371
104832	129544	380
104843	121657	350
104855	116507	381
104906	127588	556
104917	137219	2310
104929	120050	343
104940	117422	352
104952	122838	451
105004	118408	370
105015	118392	424
105027	117297	354
105038	116816	379
105049	126935	3656
105101	139264	1930
105112	119713	454
105124	115794	425
105136	121251	528
105147	119988	411
105158	118877	445
105210	124546	497
105221	121746	444
105232	114864	355
105245	112155	328

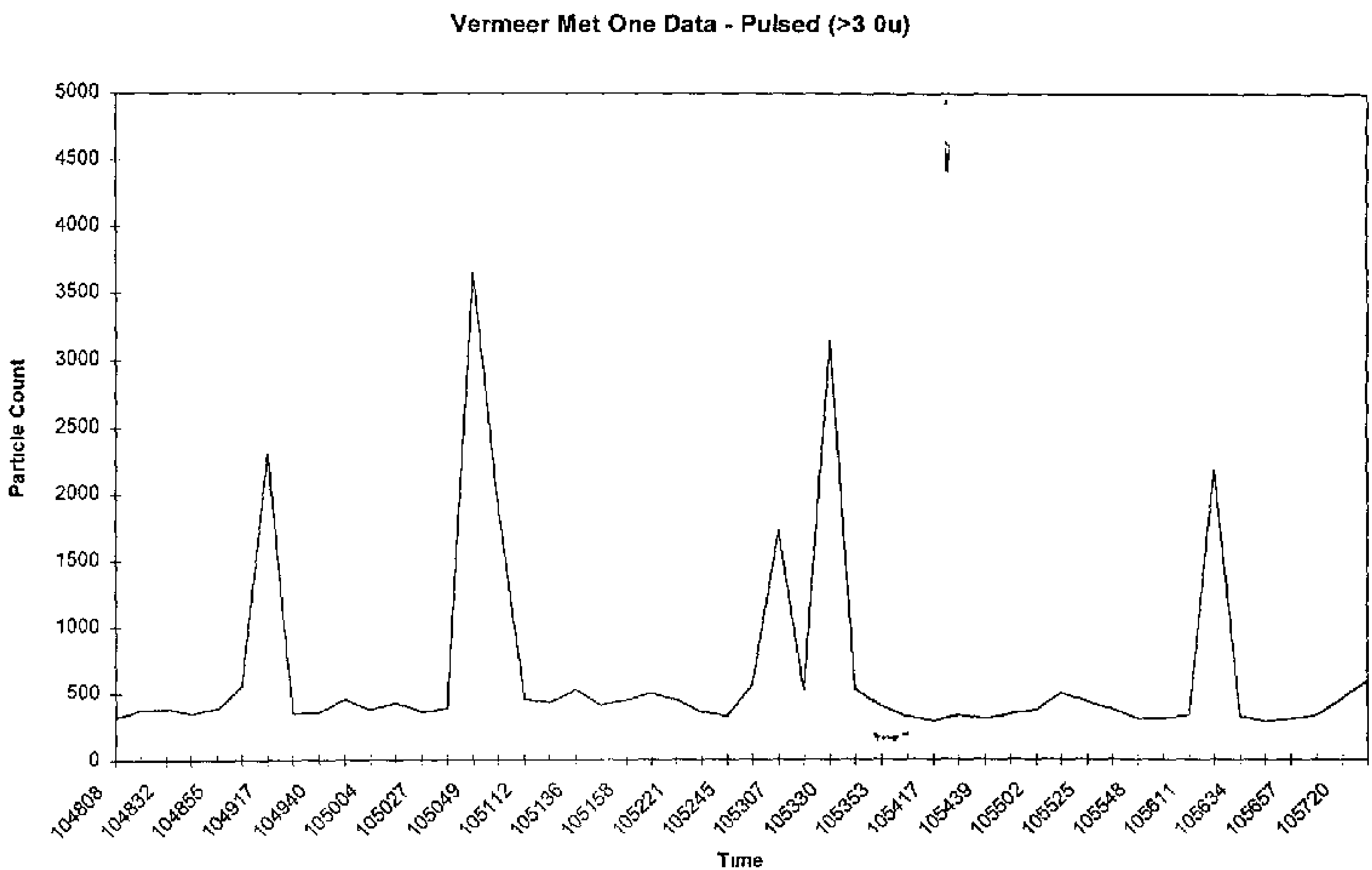
	# Particles	# Sample Counts
P-0 3Avg=	119886	50
P-3Avg=	649	

105256	120464	565
105307	134614	1727
105319	115956	520
105330	104057	3143
105341	124102	529
105353	118672	400
105404	115350	323
105417	116780	293
105428	116664	336
105439	115042	308
105451	120790	344
105502	124652	372
105513	119994	504
105525	119374	433
105537	123213	379
105548	114728	307
105600	116461	306
105611	119387	338
105623	128319	2188
105634	116234	331
105645	111339	290
105657	113966	310
105709	116051	333
105720	121648	464
105732	123846	589

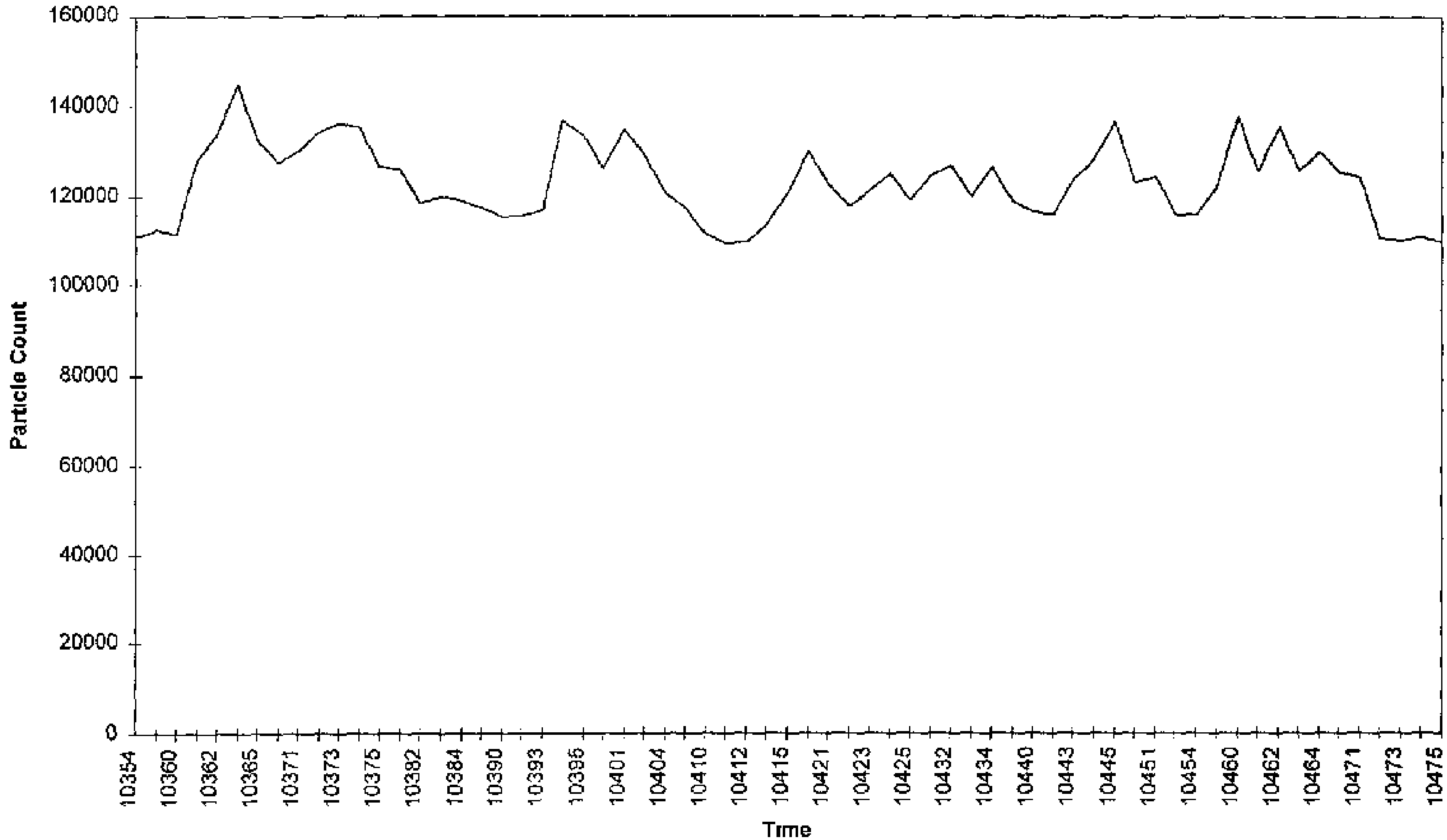
Met stopped @ 10 57 42
Filter stopped @ 10 57 47
Datalogger stopped @ 10 57 53

Vermeer Met One Data - Conv (>3.0u)




Vermeer Met One Data - Pulsed (>3 0u)
Particle Count
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
104808
104832
104855
104917
104940
105004
105027
105049
105112
105136
105158
105221
105245
105307
105330
105353
105417
105439
105502
105525
105548
105611
105634
105657
105720
Time

Vermeer Met One Data - Conv (>0 3u)



Vermeer Met One Data - Pulsed (>0.3u)