EFFECT OF POSITION AND MOTION ON PERSONAL EXPOSURE

IN A HVLP SPRAY PAINTING OPERATION

John L. McKernan

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Approved by:

Research Advisor

Reader

Reader

Abstract

JOHN L. Mc KERNAN. Effect of Position and Motion on Personal Exposure in a HVLP Spray Painting Operation. (Under the direction of MICHAEL R. FLYNN)

Worker exposure to particles is a problem in most spray painting processes. Previous studies, using a stationary mannequin and simple spray nozzle, showed that dimensional analysis could be used to correlate a dimensionless breathing zone concentration (which requires knowing the gun transfer efficiency) with a dimensionless nozzle pressure term (the Carlton number). This work expands on that study by using a real high volume-low pressure (HVLP) gun, and adding a representative spraying motion. A robot-mannequin, capable of holding and actuating the spray gun, and also performing a repeated side-to-side spraying motion was used. Vacuum pump oil was sprayed onto a flat plate in a wind tunnel to determine the relationship between nozzle pressure and breathing zone concentration. "Breathing zone" samples were collected using a cassette modified to mimic the IOM inlet.

Data collected in the absence of motion show that the dimensionless concentration in the 90° position is lower than the 180° position until a crossover point is reached at low values of the Carlton number (8×10^5). After this point, the dimensionless breathing zone concentration in the 180° position is lower than in the 90° orientation. For the case with motion, the importance of position to dimensionless breathing zone concentration was mitigated. Using task representative Carlton number values (alpha valueș) allows for simplification of the results. Alpha values for the 90° and 180° orientations without motion were 0.232 and 0.028. It was observed that the motion mitigated the positional effect in such a way as to make the alpha value for motion close to the average of the two no motion alpha values, 0.102. These results allow for the supposition of a formula to predict breathing zone concentrations or transfer efficiencies for conventional and HVLP spraying guns. The results also stress the association between contaminant generation, transport, and exposure. Models, such as the one used, are beneficial because they relate exposure to processes parameters that can be controlled to reduce it.

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1.0 Introduction

Spray painting is the method of choice in industry to coat and finish many products, from furniture to automobiles. There are many different types of spray guns to choose from, each uses a different physical process such as electrostatic, air assisted airless, and low pressure air atomization to coat the workpiece. Although spray application gives a better finish than other methods, it has the disadvantage of creating a fine particulate "overspray" which reaches the workers' breathing zone. Inhalation of this overspray is a major hazard because it contains pigments, solvents and binders. The inorganic compounds which make up the pigments commonly contain lead, chromium, cadmium. Many compounds of these elements induce respiratory, systemic, and possibly cancerous effects.[7] Solvents and binders such as polyisocyanates, n-hexane and toluene are also constituents of the overspray and have been associated with skin, eye and respiratory effects.[10]

Since there are a multitude of health effects related to overspray exposure, efforts are being made to control it. The favored approach is the use of engineering controls. Engineering controls commonly used in the spray painting process are local exhaust ventilation, and recently the use of new types of spray systems with more efficient application methods.

Designing controls for industrial operations is a difficult engineering undertaking. The American Conference of Governmental Industrial Hygienists

(ACGIH) has attempted to simplify the design process for local exhaust ventilation systems by providing engineers with VS plates.[1] Successful reduction of airborne contaminants by the use of these suggested designs is not guaranteed. Only after building the ventilation system can it be tested for proper contaminant control. The development and use of models may make this process of ventilation design more cost effective. Using a model, predictions about the concentration in the proposed system can be made before it is built, thus setting the stage for optimization.

The ability to reduce excess particles emanating from the spraying process is also an important engineering control. Industry and some states are very interested in reducing the overspray created by spraying systems. It saves industry money if they can improve the quality of finish while decreasing the amount of paint wasted in the overspray. States are more concerned with human safety issues, such as fires, exposure to the overspray, and complying with emissions standards for air quality. In this work, a new high volume low pressure (HVLP) spray gun was used. The HVLP spraying system has been shown to reduce exposures while increasing the quality of finish on the product.[9] The HVLP was used to test how well it would fit into a previously developed model by Carlton and Flynn.[2] There was also an interest in whether or not the gun, acting as an engineering control, increased transfer efficiencies while decreasing exposure to the contaminant as claimed.[9, 10]

It is advantageous to have an estimate of the reduction in worker exposure, before spending money to update or redesign the current engineering controls in a facility. In the past, a proposed engineering control would have to be installed to evaluate its effectiveness. Since this procedure is expensive and sometimes impractical, methods to investigate the efficacy of a control before it is implemented are needed. This ability to predict exposure will allow for a more effective use of engineering controls. The Carlton-Flynn model may enable hygienists to predict breathing zone concentrations for spray painting operations. The model uses mathematical equations involving the dominant parameters of a spray painting task. The model has been evolving through continued exposure assessment research.

Previous studies using elementary models of flow around a worker with passive introduction of the contaminant and simple exposure assessment have been done by researchers such as Kim and George, et al.[12, 8] Kim also conducted breathing zone concentration evaluations for a simple spraying system, taking into account the source momentum. It was discovered that the added momentum negates the recirculation vortex documented by George [8], and results in a reduction of breathing zone concentration when compared to the case with passive introduction of the contaminant.[13, 8]

The end result of this continuing research is to develop a working model which can evaluate possible exposures for a multitude of spraying operations. This working model can then facilitate estimates of worker exposures in any spray painting task. Industries stand to reduce paint particulate and solvent exposure to workers, saving money and preventing occupational disease.

2.0 Theory

In previous experiments by Kim [12, 13], George [8] and Carlton [2, 3], factors which contribute to exposure in spray painting tasks were determined. Of these, the dominant ones are ventilation, contaminant generation rate, and work practices. Carlton [2] most recently expanded on past work to develop and test an empirical-conceptual model. All of the relevant task defining parameters were included in the model and were combined to create two dimensionless terms, developed by dimensional analysis, to relate the spray painting task to worker breathing zone concentration.

The following parameters were significant in the Carlton-Flynn model; nozzle pressure at the cap of the spray gun in pounds per square inch gauge (p_n), height of the mannequin in feet (H), viscosity of the liquid to be sprayed in centipoise (μ_l), velocity of the wind tunnel in feet per minute (U), concentration in the breathing zone of the mannequin in milligrams per cubic meter (C), width (breadth) of the mannequin in feet (D), and contaminant generation rate in grams per minute (m_0).

There are three processes common to all liquid spray painting tasks. They are; droplet formation, droplet transfer, and droplet transport. These three processes define a conceptual model to predict a worker's exposure to paint overspray. [2] The dimensionless terms used in the model are a combined expression of the task defining parameters and the dominant processes. Their groupings represent related mechanisms which lead to exposure. The expressions for the dimensionless terms are:

Dimensionless Nozzle Pressure Term (Carlton Number): $\dfrac{p_n H}{\mu_l U} = \dfrac{\text{droplet transport}}{\text{droplet transfer}}$

Dimensionless Breathing Zone Concentration Term: $\dfrac{CHUD}{m_o}$

The dimensionless breathing zone concentration was defined by Carlton[2]. Using dimensional analysis, the following dimensionless representation of the model was developed:

$$\frac{CUHD}{m_o} = \Phi\left(\frac{m_a}{m_l}, \frac{p_n H}{\mu_l U}, \text{orientation}\right)$$

The model indicates the concentration group $CUHD/m_o$ depends on worker orientation to the freestream and two other nondimensional groups; the air-to-liquid mass flow ratio m_a/m_l and the dimensionless pressure group p_nH/μ_lU. The empirical work indicated that $CUHD/m_o$ is a strong function of the quantity p_nH/μ_lU and worker orientation. This can be seen in Figure 1.

The previous study [2] utilized a stationary mannequin holding a ¼ J nozzle in two possible orientations (90° and 180°), a flat plate, and wind tunnel to develop the model. The ¼ J spray nozzle was used because it had characteristics, such as droplet size distributions, and m_a/m_l values, similar to a commercial hand-held spray gun. Results from this research conducted by Carlton (1996) are shown graphically in Figure 1. The data suggest that for Carlton numbers greater than 5 x 10^6, the dimensionless concentration is higher in the 90° orientation. The data also suggest that there is a defining region of Carlton numbers where conventional high pressure spraying systems operate. This region is defined by Carlton numbers which most closely represent a real operation. Table B.1 in Appendix B contains a detailed description of the calculations used to represent a real operation. In Figure 1, the plateau regions in both orientations above Carlton number values of 1.3 x 10^7 represent these real operation areas. Because the dimensionless concentrations at and above these Carlton number values do not change, we associate one value for the dimensionless concentration over the whole range of realistic operation for each orientation. These constant values for concentration are called the alpha (α) values. From the work displayed in Figure 1, these values are:

$$\alpha_{90} = 0.13$$

$$\alpha_{180} = 0.006$$

The HVLP operates in a range of Carlton numbers between 3 x 10^5 and 2.5 x 10^6, lower than previously investigated.[2] A major hypothesis of this work is that the

HVLP will follow the defined trends in the 90 and 180° orientations shown in Figure 1.

Carlton (1996) completed field evaluations of his model, the results of which are in Figure 2.[2] Using volunteer workers, Carlton measured all of the necessary parameters needed for the model to see if the predicted concentrations matched their actual task exposures.

Figure 2 shows the model was fairly accurate, often within one standard error of the mean. Considering all of the data points, 71% of the measured task exposures are within a factor of three of the model prediction. This accuracy is satisfactory in light of the fact that the model is based solely on dimensional relationships. The measured field exposures tended to be less than those predicted by the model, but statistical analysis indicated that this was not significant. It was determined that the model was sufficient to make predictions of the average breathing zone concentration for workers performing spray painting tasks.

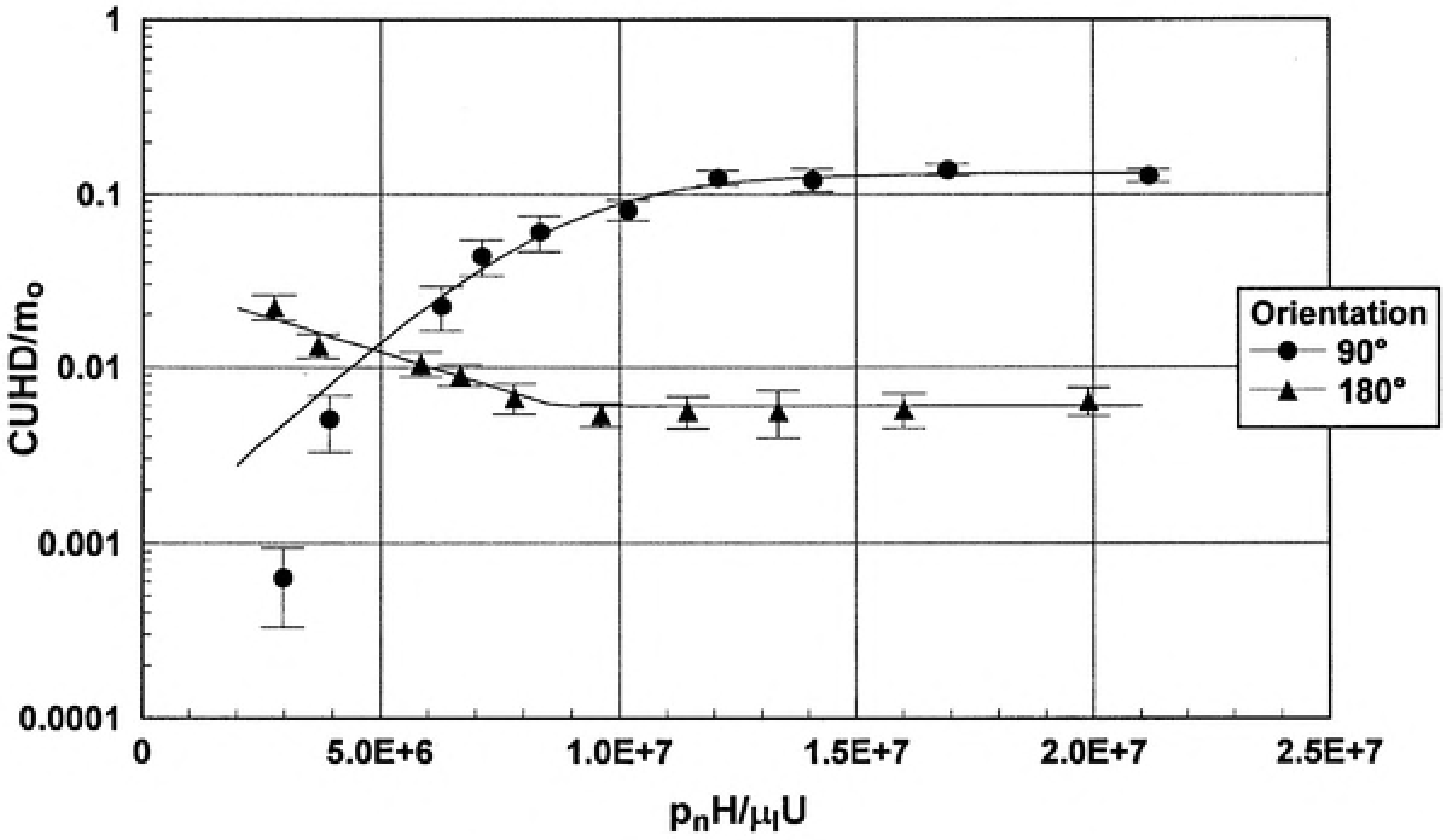


Figure 1: Functional relationship between the dimensionless groups identified by dimensional analysis without motion. (from Carlton, et al.)

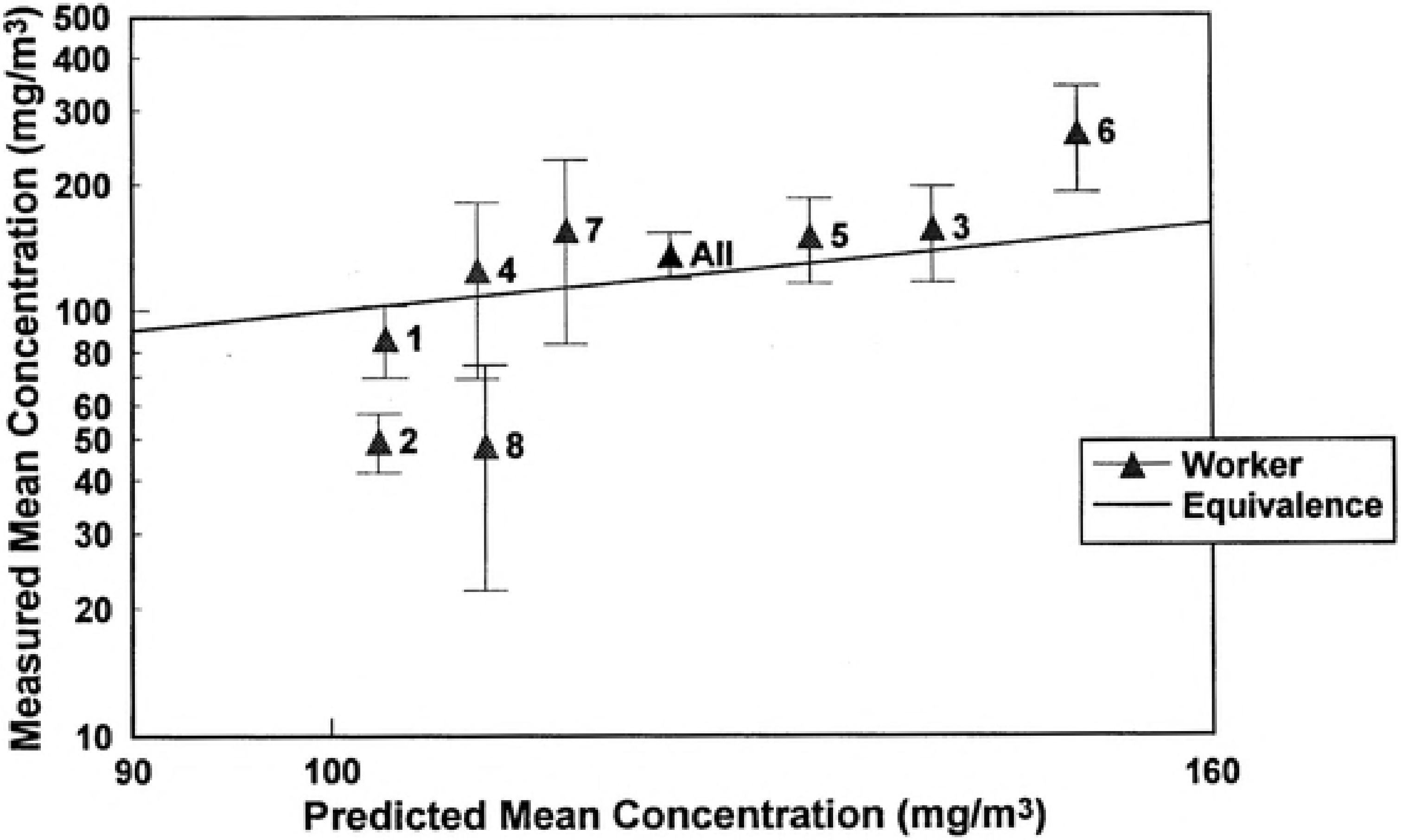


Figure 2: Measured mean worker exposures for the field study and their model predictions. Most of the predictions are within one standard error of the means.

The previous results indicate that spray painting is a variable exposure task and is difficult to characterize. Characterization is further complicated by the fact that each worker has different experiences that directly affect their individual work practices. This may explain some complications seen in the previous evaluation of the model, because no consideration was made for variations in work practices.

2.1 Objectives of Study

The objective of this research is to determine the validity of the suggested empirical conceptual model. The addition of motion to the experimental trials and the use of an HVLP spray gun will help assess if the relationships shown in the Carlton-Flynn model are valid. The results of this experiment will ascertain if the model can be generalized to different spray operations.

This work expands on Carltons' by using the HVLP spraying system which operates at much lower pressures than a conventional system, like the 1/4 J. Using the HVLP as an engineering control has been highly recommended for industry. A comparison of the HVLP and conventional systems done by the National Institute for Occupational Safety and Health (NIOSH) showed that the HVLP system was approximately 30% more efficient than conventional systems. This efficiency was based on measured film thickness from the target workpiece. Overspray measured in the HVLP operation was ½ that in the conventional operation. [9] In using techniques similar to those outlined by Carlton (1996) in this experiment, it is hypothesized that the new HVLP will follow the previous trends for the 90 and 180° positions as defined by the ¼ J.

A second objective of this work is to determine if data from the mannequin with a representative spraying motion would fit the model. It is believed that moving the gun hand of the mannequin back and fourth horizontally while spraying the workpiece will produce data that is more task-representative. There are limitations to this hypothesis. The mannequin will be spraying the workpiece in an arcing motion, with the gun close in the middle of the arc and far from the workpiece at the ends. Also, the fact that the gun trigger cannot be "fanned" like a real process limits the hypothesis of realistic representation by the moving mannequin. Both of the limiting factors mentioned may increase the measured breathing zone concentration.[6]

3.0 Methods

3.1 Laboratory Setup

The laboratory experiment required many pieces of equipment, such as:

1. a wind tunnel through which a uniform freestream could be varied
2. a mannequin to represent the worker and objects to represent the workpiece
3. a spraying system to deliver the simulated paint to the workpiece
4. an active sampling technique which would provide data for exposure concentrations

The wind tunnel used in this experiment was an 8 foot deep by 25 ft^2 tunnel in Baity Air Engineering Laboratory at UNC Chapel Hill. The wind tunnel is capable of producing uniform freestream velocities by the use of a flared inlet opening, resembling a bell, and a pegboard rear wall. It was possible to vary the freestream in the wind tunnel from 40 to 325 fpm using a Toshiba Tosvert-130H1, power source frequency inverter attached in-line to the system fan. The system fan was a New York Blower Co. general purpose 48" diameter fan. The wind tunnel was calibrated using an Alnor model 8565 nickel-wire thermoanemometer. The thermoanemometer was calibrated for use by implementing a ventilation system with an orifice meter in the ductwork. The orifice meter was previously calibrated in the duct work using a primary standard Dwyer pitot tube and manometers. A calibration curve was developed for this data set (Appendix A, Figure A.1). The thermoanemometer reading was calibrated with comparison to the pitot tube calculated velocity to correct to a 'true' velocity reading. The velocity read directly from the thermoanemometer was found to be approximately equal to the calculated 'true' velocity within the range of concern, so no correction factor was utilized when taking thermoanemometer readings in the wind tunnel. A calibration curve for the thermoanemometer velocity vs. 'true' velocity is in Appendix A, Figure A.2.

The calibration of the wind tunnel was done by averaging the velocity measurements, read from the thermoanemometer, for 16 points on a central vertical plane. This was done for 8 separate freestream velocities between 43 and 325 fpm.

Velocity measurements were correlated to static pressure readings taken with a large pitot tube upstream of the system fan. A wind tunnel calibration curve was made from this data set (Appendix A, Figure A.3).

The mannequin in this experiment was quite unique. It utilized electric motors and servo controls to actuate the trigger finger, and in later motion experiments, move its right arm in an arc about 135° wide. The mannequin was of the department store variety, but cut just above the knee to accommodate its use in the wind tunnel. It measured 4.25 feet high (H) and 1.17 feet at the chest (D). The HVLP gun was held in its right hand and actuated by use of the servo controlled index finger. There were two mannequin orientations in this experiment. It could face the rear of the wind tunnel, the 180° position, or it could face perpendicular to the freestream, in the 90° position. The mannequin in both cases sprayed the gun at a flat metal plate which represented the workpiece. The gun was held eight inches away from a 24 x 36 inch flat plate in both orientations of the no motion studies. When motion was implemented, the gun was held 8" away at the closest point in the arc motion of the arm, from a 36 x 36 inch plate in both orientations.

In place of spraying paint, we chose a non-volatile, non-toxic compound to apply to our workpiece. This compound was paraffin wax or vacuum pump oil (Inland 99, MSDS attached). It met all of the safety requirements of the university and research staff and was about the same consistency as the previously used corn oil.

Initially, corn oil was used because it was also considered a relatively safe compound and had about the same viscosity as enamel paints.

In using the new vacuum pump oil, it was important to find it's viscosity at different temperatures to correct our data for temperature later. Because the experiment was done in the summer time, a temperature range from 68 to 98 degrees Fahrenheit was chosen. Viscosity measurements were done using a Haake falling ball viscometer in an adjustable temperature bath, and a stopwatch. A calibration curve for the measured viscosity (μ_l) of the oil at different temperatures in the predetermined range is in Appendix A, Figure A.5.

The compressed air system used was a Speedaire 5 horsepower air compressor pump model 5Z641, mounted on a large air reserve tank. The compressor delivered a set 110 psig through the outlet regulator, which was then reduced to 90 psig in a secondary pressure regulator. This pressure reduction is done to prevent "starving" of the spraying system which could cause pressure variations at the gun cap and pressurized paint feed tank. The pressurized paint feed tank was a DeVilbiss QMG T-5220 galvanized dual regulator tank. The two regulators on the pressurized feed tank were used to set the pressure inside of the feed tank and to set the air pressure going into the spray gun. The tank regulator was set to 10 psig for all experiments. The gun regulator had multiple settings which corresponded to different cap pressures from 10 psig down to 2 psig. A diagram and pictures of the spraying equipment used are in Appendix B.

The high volume low pressure (HVLP) gun was a DeVilbiss MSV-533-4-FF with a 33A air cap. It was specified to operate at a maximum spraying capacity of 18.75 cfm at 10 psig at the cap. The last piece of equipment in need of calibration was the HVLP spray painting gun. It was decided that for all experiments the gun would retain one fan pattern and liquid feed setting. These two parameters could be kept fixed because their adjustment settings were built into the gun. The fan pattern was shown to not significantly effect the volumetric flow rate through the cap of the gun. This was determined by replacing the 33A air cap on the gun with a factory modified one which measured air pressure in the horn and cap separately. Volumetric air flow rate was then measured using a Collins Inc. primary standard spirometer. The volumetric air flow rate was determined by attaching the gun cap to the intake side of the spirometer. The time it took for the air to raise the bell of the spirometer to a predetermined height was recorded. Using this recorded time, and knowing the air pressure, the volume going into the spirometer was calculated. Once the volume was attained, the mass of air coming from the gun (m_a) could be calculated by using the known density of air at the room temperature. Spirometer readings were done for the five cap pressures that were used: 10, 8, 6, 4, 2 psig.

Personal sampling was done following NIOSH Method 0500 for total nuisance dust. This method calls for the use of 37 mm polyvinyl chloride (PVC) filter membranes with 5 μm pore size and a sampling rate of 2 liters per minute.[17]

Sampling was done in the experiments using a modified 37mm cassette which mimics the IOM inlet. The modified cassette samplers were used partly because of the need to be able to compare data from previous experiments. Also, we assumed that the modified cassette sampler would give results which were more representative of the actual mannequin exposure. IOM samplers are able to collect particles more efficiently, partly due to the properties of the opening in the cassette.[15, 16, 5] A large limiting factor for our imitation IOM samplers were that they did not account for loss of the sampled material on the walls of the cassette, as the true IOM does.

The modified cassettes were fastened to the shirt collar of the mannequin while it was performing the spray tasks in the wind tunnel. The cassettes were affixed such that the filter membrane was held parallel to the body of the mannequin. This method counteracts the effect of gravity to settle out overspray particles to or from the filter surface. Prior to gathering data, a test was done to see whether the upstream or downstream side of the mannequin had more exposure in the 90° position. This test was not performed for the 180° position because it was assumed that the exposure would be the same on both sides. The test for the 90° position showed that the downstream side (right lapel) produced the higher exposures. Therefore, sampling was done from the mannequins right side throughout all of the experiments.

Sampling pumps were used to sample through the cassette system. Nalgene tubing was used to run from the cassette samplers to the personal sampling pumps.

The pumps were SKC Aircheck sampler model 224-PCXR8. The pumps were run for varying amounts of time, depending on loading of the filters. The NIOSH method 0500 recommends a mass collection on the filters between 0.1 and 2.0 mg.[17] This corresponded to sampling times of between 3 and 10 minutes for each of the experimental trials.

The sampling medium used were SKC 225-8-01 low-ash, 5μm pore size PVC filters. The filters were analyzed using a gravimetric technique. A Cahn 27 automatic electrobalance, was used for gravimetric analyzation.

3.2 Laboratory experimental design

The design of the actual experiment was straightforward. There were two mannequin orientations and motion settings. The orientation was designated as the direction the gun sprayed relative to the freestream. This was either parallel with the freestream (180°) or perpendicular to the freestream (90°). Motion was either on or off. When in motion, the mannequin moved its arm in a 135° arc varying the spray gun distance to plate from 8 to 14 inches. Using a frequency counter, the motion was measured and found to be 8.25 cycles per minute (0.1375 Hz).

There were five different gun cap operating pressures that could be varied from 2 through 10 psig. The five cap pressures were converted to five Carlton numbers, since all other five variables were known. Thus, the experiment was run to determine the dimensionless concentration term for exposure evaluation.

Since there were five Carlton numbers, two positions and two motion settings, at least twenty experimental runs were needed. Truly, fourty runs were performed to be sure the results were reproducible.

4.0 Results

Experimental data only partially supports the Carlton-Flynn exposure model. Because the HVLP spraying system and the 1/4 J nozzle operate over different ranges of Carlton numbers, they are not directly comparable. The HVLP gun data in Figure 3 shows, for the case without motion, that the crossover point for the position effect happens at very low Carlton numbers as compared to the ¼ J (see Figure 1). It is also observable in Figure 4, that positional crossover happens at a Carlton number of 8×10^5 and a dimensionless breathing zone concentration of 0.028 for the HVLP gun, compared to values of 5×10^6 and 0.01 for the ¼ J, respectively. Maximum values for the dimensionless breathing zone concentrations for the HVLP were 0.4 and 0.1 for the ¼ J nozzle in the no motion test comparison. It is interesting to note that in the 180° position with no motion, the ¼ J and the HVLP data fit well. The 90° data for the HVLP on the other hand, is quite independent of the ¼ J data. This suggests that in the 90° orientation, the trend in the Carlton-Flynn model for high pressure conventional spraying systems with no motion does not fit the HVLP system data. This data, with standard deviations about the mean, is displayed in Figure 3. The best-fit lines from linear regression for the HVLP data without motion are:

90° orientation: $$\frac{CHUD}{m_o} = 3x10^{-7}\left(\frac{p_n H}{u_l U}\right) - 0.1336 \qquad r^2 = .93$$

180° orientation: $$\frac{CHUD}{m_o} = 3.23x10^{-2} \exp\left(-1.94x10^{-7}\frac{p_n H}{u_l U}\right) \qquad r^2 = .95$$

Alpha values were also determined for the two orientations with no motion. They are as follows:

$$\alpha_{90,\ \text{no motion}} = 0.232\ (1.3 \times 10^6 \leq \text{Carlton number} \leq 2.5 \times 10^6)$$

$$\alpha_{180,\ \text{no motion}} = 0.0281\ (1.1 \times 10^6 \leq \text{Carlton number} \leq 2.5 \times 10^6)$$

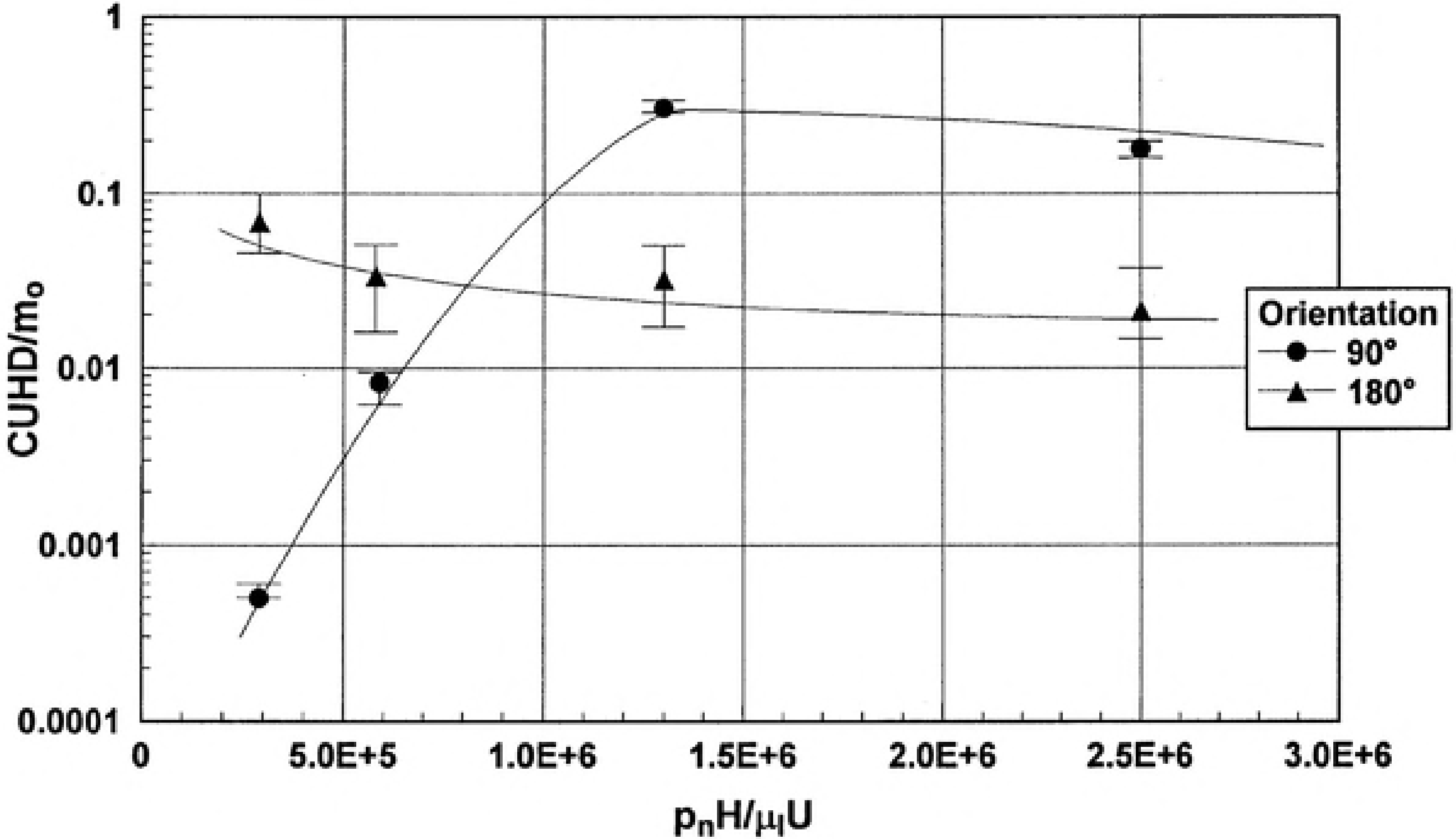


Figure 3: Functional relationship between the dimensionless groups using the HVLP data without motion.

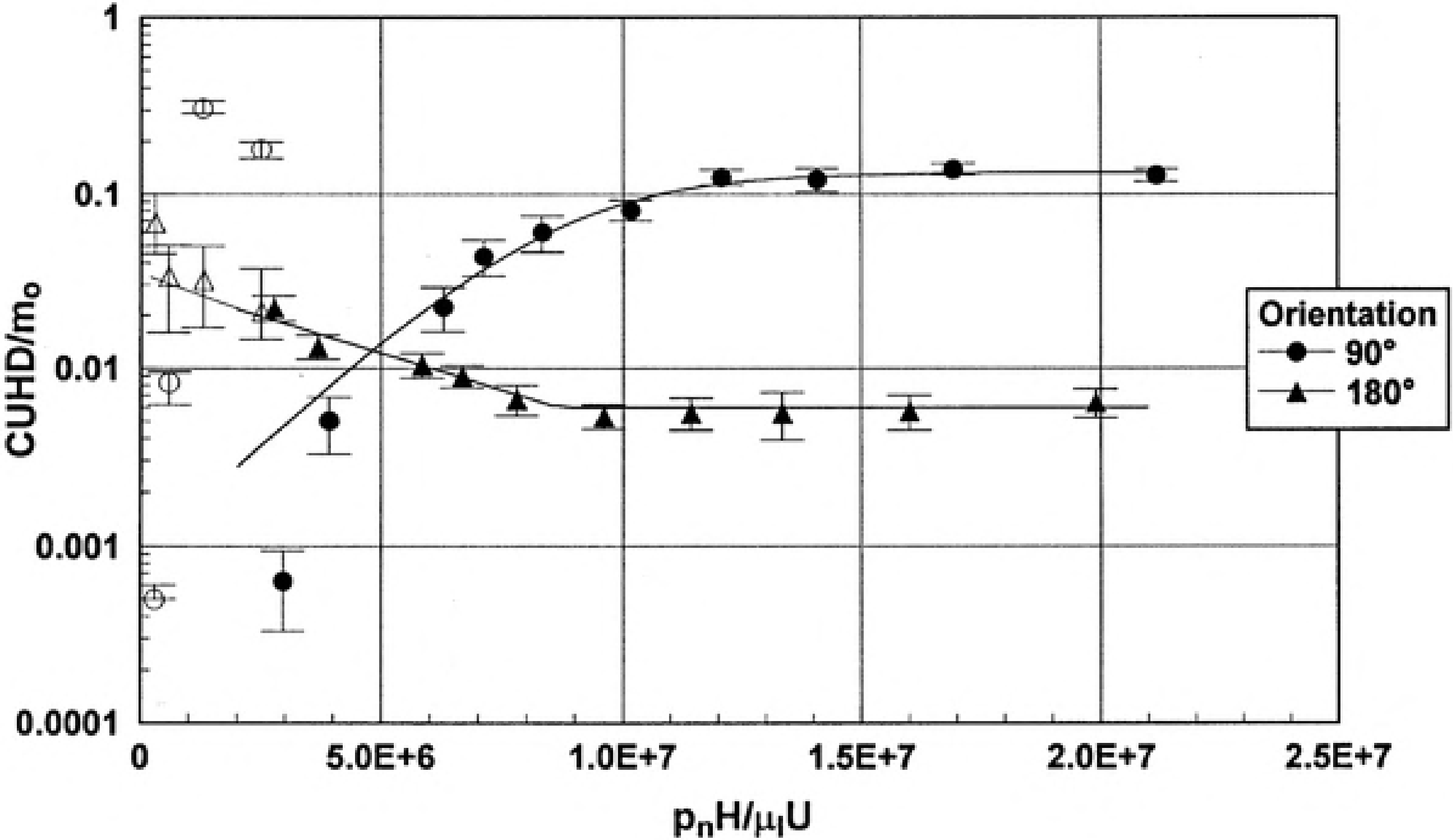


Figure 4: Functional relationship between the dimensionless groups. The graph is a composite of all the data without motion taken thus far using the current model.

This study also included a motion effect analysis on dimensionless concentration values. The motion experiment data, with standard deviations about the mean, are displayed in Figure 5. The figure shows that motion collapses the positional effect seen in the previous no motion case. This collapse brings both curves close to an average value of the no motion data in the Carlton number region between 1.1×10^6 and 2.5×10^6. Since the data overlapped in the range for task representative Carlton numbers, a statistical test was performed. The test was used to discern if there was still an effect of position on dimensionless concentration with motion. See Appendix B for a description and outcome of the test performed. In summary, the test proved that the motion did indeed mitigate the positional effect to a degree that it can be said that both curves are not significantly different in the range of task representative Carlton numbers. Positional crossover happened at a Carlton number of 8×10^5 and a dimensionless breathing zone concentration of 0.028 for the stationary HVLP gun, and at 7×10^5 and 0.1 respectively for the moving HVLP setup. The maximum values for the dimensionless breathing zone concentrations for the stationary HVLP experiment were 0.4, and 0.2 for the moving HVLP experiment. Since there was no positional effect for motion, the data is expressed as an average concentration in the Carlton number region defined above. Therefore, there is only one alpha value expression for the motion experiment:

$$\alpha_{90\text{-}180,\ motion} = 0.102 \ (1.1 \times 10^6 \leq \text{Carlton number} \leq 2.5 \times 10^6)$$

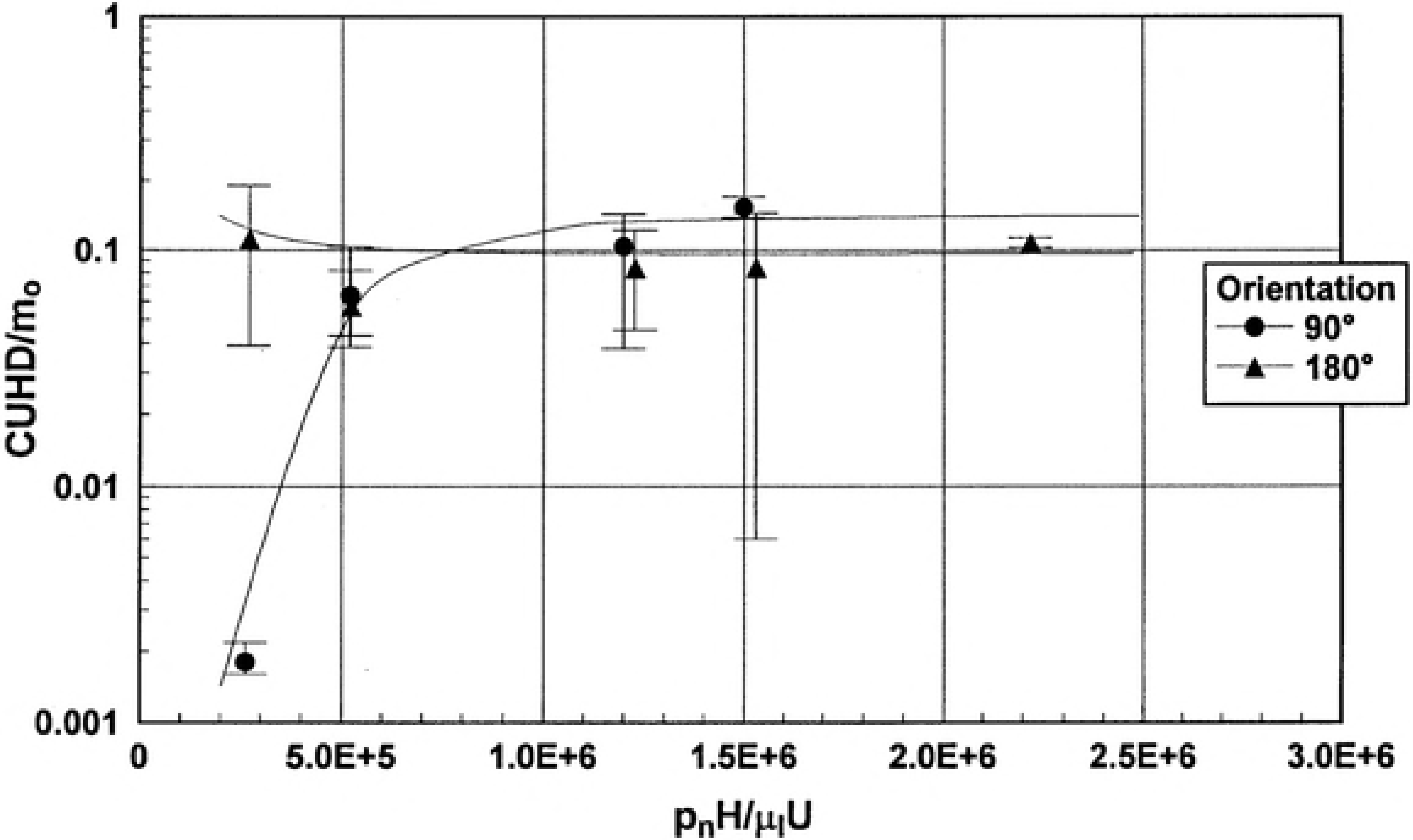


Figure 5: Functional relationship between the dimensionless groups using motion data from HVLP experimental trials.

5.0 Discussion

The model previously defined using the ¼ J nozzle does not generalize completely to the HVLP spraying system. Figure 4, suggests that the trend seems to hold only in the 180° orientation no motion case. It is interesting that the trendlines for the two different spraying systems look similar, but occur over different ranges of Carlton numbers (See Figures 1 and 3). The HVLP data may be better understood by an explanation of how each system operates.

The ¼ J uses a sonic airstream to atomize the sprayed liquid. This airstream is characterized as compressible flow. When the compressed (sonic) airstream exits the cap of the gun, it expands instantly to re-equilibrate itself with atmospheric pressure. This expansion is equivalent to an explosion, which violently atomizes the particles. This exploding airstream creates many small particles which do not impact on the workpiece and contribute significantly to breathing zone concentration.[19] The HVLP airstream is subsonic, but a higher volume of air and spray liquid is released compared to a high pressure system. This high volume of air under lower pressure blows the sprayed liquid apart and creates larger paint particles. The particles are then propelled toward the workpiece by the airstream where they are more likely to impact because of their size. This translates to the HVLP gun having a higher transfer efficiency.[19]

Differences in sampling technique may explain some of the variability between the ¼ J and the HVLP concentration measurements. The previous 1/4 J experiments used open-faced cassettes to collect samples to calculate breathing zone concentration. This experiment used an imitation IOM sampler to collect breathing zone concentrations. Loss factors due to the inlet and losses on the walls of the cassette were not adjusted for in this experiment.

Motion mitigated the position effect. Dimensionless breathing zone concentration tended toward the average value for the two positional trendlines in the no motion experiment. The distance to the plate varied, and the trigger on the gun was held back fully and not "fanned" as a true worker would have operated the gun. When the plate distance is not kept constant, excess overspray is generated adding to the breathing zone concentration. Not fanning the trigger lets the worker spray off of the edges of the target, also increasing the breathing zone concentration.[6]

Since results of the current experiments suggest that the position effect may be mitigated by motion, perhaps an average of the values obtained from the stationary estimates would be a reasonable estimate of the dimensionless concentration. If this approach is applied to the constant values from task representative Carlton number ranges for the 1/4 J data, one obtains:

$$\frac{(\alpha_{90} + \alpha_{180})}{2} = \frac{(0.13 + 0.006)}{2} = 0.068$$

While the HVLP with motion was 0.102. Thus, if one selected the same paint, booth velocity, worker characteristics, and liquid flow rate, the expected ratio of the HVLP dimensionless breathing zone concentration to that of a conventional gun should be:

$$\frac{\left(\alpha_{90-180,\text{motion}}\right)}{0.068} = 1.5$$

By mathematical manipulation, the following expression results:

$$\frac{C_{HVLP}}{C_{conv}} = 1.5 \cdot \left(\frac{1-\eta_{HVLP}}{1-\eta_{conv}}\right)$$

Where C is the breathing zone concentration and η is the transfer efficiency. Thus, if an HVLP gun delivers a transfer efficiency of 80% and a conventional gun 60%, then the HVLP breathing zone concentration should be 75% of the conventional if the time to apply the paint is the same.

6.0 Conclusions

From previous experiments, it seems that a spraying system which operates below the high pressure system (1/4 J) crossover point should have a lower breathing zone concentration in the 90° orientation. This experiment, utilizing an HVLP gun which operates well below the crossover point, illustrates that this assumption of less exposure in the 90° orientation is not true. Data for the 180° orientation with no motion follows the trendline from the previous experiment well, but HVLP data for the 90° orientation suggests that a mechanism not considered in the Carlton-Flynn model may be resulting in substantially higher dimensionless breathing zone concentration values than previously imagined. This experiment provides data that, in three out of four experimental cases, does not support the Carlton-Flynn model. Only in the case of no motion in the 180° orientation did the data from the HVLP system show agreement with the suggested model. There is a definite increase in dimensionless breathing zone concentration using the HVLP in the 90° orientation in comparison to the ¼ J with no motion. In the trials with motion, neither orientation agreed with the ¼ J assumptions.

The trials without motion using the HVLP system showed that the dimensionless breathing zone concentration is constant above Carlton number values representative of a real spray painting task for the two orientations without motion. The positional effect appeared to be mitigated by the motion of the mannequin.

Motion tests resulted in a dimensionless breathing zone concentrations that, above Carlton numbers representative of a real spraying task, is approximately the *average* value of the two no motion task representative regions. It must be noted that the variability with motion was much higher than the no motion studies. This variability suggests a mixing or "stirring" effect in the wind tunnel when the mannequin is moving.

It should be noticed that now it is possible to use the results of this and the previous experiments to estimate worker breathing zone concentration by using the predefined alpha values (the task representative Carlton number) for the ¼ J and HVLP systems. The relation between the breathing zone concentration, spraying systems, and transfer efficiency can be expressed in the formula:

$$\frac{C_{HVLP}}{C_{conv}} = 1.5 \cdot \left(\frac{1-\eta_{HVLP}}{1-\eta_{conv}} \right)$$

Where C is the breathing zone concentration and η is the transfer efficiency. The relation allows for estimation of the breathing zone concentration when using either system. Expanding on the results obtained in this experiment, by gathering data from a conventional hand-held spraying system and an HVLP system is a topic suggestible for further studies. The comparison of the two systems with more data will give a better understanding of the relationship above, and determine if it is applicable.

7.0 Appendix A:

Calibration and Raw Experimental Data

Table A.2 Process Measurements

Run Number	Static Pressure (in wg)	Freestream Velocity (fpm)	Liquid Temp (F)	Viscosity	Relative Humidity %	Air Temp (F)	Gauge Pressure (psig)	Cap Pressure (psig)	Cap & Horn Pressure (psig)	Orientation	Motion
1	0.16	150.3	81	56.94	62	81	16	1.5	2.5	90°	NO
2	0.12	126.8	81	56.94	62	81	27	2.5	4.5	90°	NO
3	0.08	99.0	81	56.94	62	81	38	4.25	7.5	90°	NO
4	0.048	71.1	81	56.94	62	81	46	6	10.5	90°	NO
5	0.048	71.1	81	56.94	62	81	53	6.5	11.5	90°	NO
6	0.16	150.3	79	60.53	79	76	16	1.5	2.5	180°	NO
7	0.12	126.8	79	60.53	79	76	27	2.5	4.5	180°	NO
8	0.08	99.0	79	60.53	79	76	36	4.25	7.5	180°	NO
9	0.048	71.1	79	60.53	79	76	46	6	10.5	180°	NO
10	0.048	71.1	79	60.53	79	76	53	6.5	11.5	180°	NO
11	0.055	77.8	78	62.41	64	79	53	6.5	11.5	180°	NO
12	0.048	71.1	78	62.41	64	79	46	6	10.5	180°	NO
13	0.08	99.0	78	62.41	64	79	38	4.25	7.5	180°	NO
14	0.12	126.8	78	62.41	64	79	27	2.5	4.5	180°	NO
15	0.16	150.3	78	62.41	64	79	16	1.5	2.5	180°	NO
16	0.16	150.3	78	62.41	64	79	16	1.5	2.5	90°	NO
17	0.12	126.8	78	62.41	64	79	27	2.5	4.5	90°	NO
18	0.08	99.0	78	62.41	64	79	38	4.25	7.5	90°	NO
19	0.048	71.1	78	62.41	64	79	46	6	10.5	90°	NO
20	0.048	71.1	78	62.41	64	79	53	6.5	11.5	90°	NO
21	0.16	150.3	77	64.35	68	77	53	6.5	11.5	90°	NO
22	0.05	73.0	77	64.35	68	77	53	6.5	11.5	90°	NO
23	0.05	73.0	77	64.35	68	77	46	6	10.5	90°	NO
24	0.08	99.0	77	64.35	68	77	38	4.25	7.5	90°	NO
25	0.123	128.7	77	64.35	68	77	27	2.5	4.5	90°	NO
26	0.16	150.3	77	64.35	68	77	16	1.5	2.5	90°	NO
27	0.16	150.3	79	60.53	58	82	16	1.5	2.5	180°	NO
28	0.12	126.8	79	60.53	58	82	27	2.5	4.5	180°	NO
29	0.08	99.0	79	60.53	58	82	38	4.25	7.5	180°	NO
30	0.05	73.0	79	60.53	58	82	46	6	10.5	180°	NO

Table A.2 Process Measurements

Run Number	Static Pressure (in wg)	Freestream Velocity (fpm)	Liquid Temp (F)	Viscosity	Relative Humidity %	Air Temp (F)	Gauge Pressure (psig)	Cap Pressure (psig)	Cap & Horn Pressure (psig)	Orientation	Motion
31	0.05	73.0	79	60.53	58	82	53	6.5	11.5	180°	NO
32	0.16	150.3	80	58.71	58	80	16	1.5	2.5	90°	NO
33	0.12	126.8	80	58.71	58	80	27	2.5	4.5	90°	NO
34	0.12	126.8	80	58.71	58	80	27	2.5	4.5	180°	NO
35	0.08	99.0	80	58.71	58	80	38	4.25	7.5	180°	NO
36	0.08	99.0	80	58.71	58	80	38	4.25	7.5	180°	NO

Table A.2 Process Measurements

Run Number	Static Pressure (in wg)	Freestream Velocity (fpm)	Liquid Temp (F)	Viscosity	Relative Humidity %	Air Temp (F)	Gauge Pressure (psig)	Cap Pressure (psig)	Cap & Horn Pressure (psig)	Orientation	Motion
101	0.16	150.3	75	68.41	47	75	16	1.5	2.5	180°	YES
102	0.12	126.8	75	68.41	47	75	27	2.5	4.5	180°	YES
103	0.08	99.0	75	68.41	47	75	38	4.25	7.5	180°	YES
104	0.05	73.0	75	68.41	47	75	46	6	10.5	180°	YES
105	0.05	73.0	75	68.41	47	75	53	6.5	11.5	180°	YES
106	0.08	99.0	75	68.41	47	75	38	4.25	7.5	90°	YES
107	0.12	126.8	75	68.41	47	75	27	2.5	4.5	90°	YES
108	0.16	150.3	75	68.41	47	75	16	1.5	2.5	90°	YES
109	0.1	113.6	76	66.35	51	76	53	6.5	11.5	90°	YES
110	0.08	99.0	76	66.35	51	76	38	4.25	7.5	90°	YES
111	0.12	126.8	76	66.35	51	76	27	2.5	4.5	90°	YES
112	0.16	150.3	76	66.35	51	76	16	1.5	2.5	90°	YES
113	0.1	113.6	77	64.35	56	77	53	6.5	11.5	180°	YES
114	0.1	113.6	77	64.35	56	77	53	6.5	11.5	180°	YES
115	0.08	99.0	77	64.35	56	77	38	4.25	7.5	180°	YES
116	0.12	126.8	77	64.35	56	77	27	2.5	4.5	180°	YES
117	0.16	150.3	77	64.35	56	77	16	1.5	2.5	180°	YES
118	0.16	150.3	77	64.35	56	77	16	1.5	2.5	180°	YES
119	0.12	126.8	77	64.35	56	77	27	2.5	4.5	180°	YES
120	0.08	99.0	77	64.35	56	77	38	4.25	7.5	180°	YES
121	0.1	113.6	75	68.41	70	75	53	6.5	11.5	180°	YES
122	0.1	113.6	75	68.41	70	75	53	6.5	11.5	180°	YES
123	0.12	126.8	75	68.41	70	75	27	2.5	4.5	180°	YES
124	0.16	150.3	75	68.41	70	75	16	1.5	2.5	90°	YES
125	0.12	126.8	75	68.41	70	75	27	2.5	4.5	90°	YES
126	0.08	99.0	75	68.41	70	75	38	4.25	7.5	90°	YES
127	0.1	113.6	75	68.41	70	75	53	6.5	11.5	90°	YES

Table A.3 Measured Flowrates and Calculated Transfer Efficiencies

Run Number	Run Time (s)	Bucket Weight (g)		Trough Weight (g)		Mass of Liquid Sprayed (g/min)	Mass of Liquid Transferred (g/min)	Mass of Liquid Overspray (m_o) (g/min)	Mass of Air (g/min)**	m_a/m_l	Transfer Efficiency	τ_2 (sec)
		Before	After	Before	After							
1	611.78	3472.6	1984.9	240	1538.7	145.9	127.4	18.5	131	0.9	0.873	5.5E-6
2	610.58	3281.6	1796.4	241.3	1509.4	145.9	124.6	21.3	165	1.1	0.854	3.3E-6
3	302.64	3167.7	2543.8	241.7	741	123.7	99.0	24.7	216	1.8	0.800	1.9E-6
4	303.25	3316.5	2678.9	239.4	733	126.2	97.7	28.5	268	2.1	0.774	1.4E-6
5	304.41	3048.4	2376.8	235.7	750.3	132.4	101.4	30.9	285	2.2	0.766	1.3E-6
6	602.65	3428.5	2203.1	208.5	1277.2	122.0	106.4	15.6	131	1.1	0.872	5.8E-6
7	303.92	3223.9	2596.3	255.5	780.1	123.9	103.6	20.3	165	1.3	0.836	3.5E-6
8	303.12	3139.6	2510.1	235.3	737.9	124.6	99.5	25.1	216	1.7	0.798	2.1E-6
9	303	3411	2760.4	240.6	743.1	128.8	99.5	29.3	268	2.1	0.772	1.5E-6
10	303.89	3251.1	2571.2	251.7	761.8	134.2	100.7	33.5	285	2.1	0.750	1.3E-6
11	305.27	3399.9	2709.5	223	738	135.7	101.2	34.5	285	2.1	0.746	1.4E-6
12	301.4	3211.1	2650.4	236.1	655.3	111.6	83.5	28.2	268	2.4	0.748	1.5E-6
13	303.76	3062.8	2517.3	241.9	668.1	107.7	84.2	23.6	216	2.0	0.781	2.1E-6
14	303.85	3587.6	2976.3	241.6	748	120.7	100.0	20.7	165	1.4	0.828	3.6E-6
15	602.35	3484.3	2312.4	239.9	1260.8	116.7	101.7	15.0	131	1.1	0.871	6.0E-6
16	603.15	3304.6	2108.6	243.8	1289.2	119.0	104.0	15.0	131	1.1	0.874	6.0E-6
17	304.11	3615.7	3052.3	244.2	717.7	111.2	93.4	17.7	165	1.5	0.840	3.6E-6
18	184.03	3525.1	3189.9	244.2	508.2	109.3	86.1	23.2	216	2.0	0.788	2.1E-6
19	183.83	3448	3094.5	249.8	524.4	115.4	89.6	25.8	268	2.3	0.777	1.5E-6
20	183.5	3376.1	3020.9	242.2	502.2	116.1	85.0	31.1	285	2.5	0.732	1.4E-6
21	188.31	3296.6	2934.2	215.3	476.9	115.5	83.4	32.1	285	2.5	0.722	1.4E-6
22	187.5	3174.2	2810.7	236.6	507.9	116.3	86.8	29.5	285	2.5	0.746	1.4E-6
23	188.44	3349.2	3008	244.2	505.4	108.6	83.2	25.5	268	2.5	0.766	1.6E-6
24	182.87	3269	2944.8	244.2	501.7	106.4	84.5	21.9	216	2.0	0.794	2.2E-6
25	303.63	3204.2	2690.6	242	671.9	101.5	85.0	16.5	165	1.6	0.837	3.7E-6
26	603.45	3113.8	2145.3	247.7	1088.3	96.3	83.6	12.7	131	1.4	0.868	6.2E-6
27	602.9	3866.4	2788.5	225.1	1152.7	107.3	92.3	15.0	131	1.2	0.861	5.8E-6

** Mass of air from cap only

Table A.3 Measured Flowrates and Calculated Transfer Efficiencies

Run Number	Run Time (s)	Bucket Weight (g)		Trough Weight (g)		Mass of Liquid Sprayed (g/min)	Mass of Liquid Transferred (g/min)	Mass of Liquid Overspray (m_o) (g/min)	Mass of Air (g/min)**	m_a/m_l	Transfer Efficiency	τ_2 (sec)
		Before	After	Before	After							
28	303.36	3697.6	3136.1	243.3	702.9	111.1	90.9	20.2	165	1.5	0.819	3.5E-6
29	182.34	3595.6	3241.7	242.2	517.5	116.5	90.6	25.9	216	1.9	0.778	2.1E-6
30	189.91	3511	3133.2	243	525.4	119.4	89.2	30.1	268	2.2	0.747	1.5E-6
31	193.04	3414	3009.2	244.5	542.4	125.8	92.6	33.2	285	2.3	0.736	1.3E-6
32	602.94	3698.3	2572.3	207.6	1170.6	112.1	95.8	16.2	131	1.2	0.855	5.7E-6
33	302.27	3497.1	2887.6	242.5	753.1	121.0	101.4	19.6	165	1.4	0.838	3.4E-6
34	182.31	3390.7	2985.9	249.3	589.5	133.2	112.0	21.3	165	1.2	0.840	3.4E-6
35	198.84	3330.2	2903	245.1	585.6	128.9	102.7	26.2	216	1.7	0.797	2.0E-6
36	182.1	3242.3	2823.4	246.1	585.2	138.0	111.7	26.3	216	1.6	0.810	2.0E-6

** Mass of air from cap only

Table A.3 Measured Flowrates and Calculated Transfer Efficiencies

Run Number	Run Time (s)	Bucket Weight (g)		Trough Weight (g)		Mass of Liquid Sprayed (g/min)	Mass of Liquid Transferred (g/min)	Mass of Liquid Overspray (m_o) (g/min)	Mass of Air (g/min)**	m_a/m_l	Transfer Efficiency	τ_2 (sec)
		Before	After	Before	After							
101	603.67	3626	2578	212.9	1097.2	104.2	87.9	16.3	131	1.3	0.844	6.6E-6
102	303	3924	3380.8	213.4	639.1	107.6	84.3	23.3	165	1.5	0.784	4.0E-6
103	182.64	3779.5	3447.7	240.6	485.9	109.0	80.6	28.4	216	2.0	0.739	2.3E-6
104	182.04	3693.4	3375.4	239.9	471.6	104.8	76.4	28.4	268	2.6	0.729	1.6E-6
105	183.81	3617.9	3305.9	227.2	431.9	101.8	66.8	35.0	285	2.8	0.656	1.5E-6
106	182.8	3423.5	3104.8	242.5	470.6	104.6	74.9	29.7	216	2.1	0.716	2.3E-6
107	302.73	3338.5	2819.7	236.8	658.7	102.8	83.6	19.2	165	1.6	0.813	4.0E-6
108	603.08	3240.2	2213.9	237.8	1121.7	102.1	87.9	14.2	131	1.3	0.861	6.6E-6
109	182.11	3528.5	3182.7	235.9	501.2	113.9	87.4	26.5	285	2.5	0.767	1.5E-6
110	222	3442.2	3036.1	241.2	555.8	109.8	85.0	24.7	216	2.0	0.775	2.3E-6
111	304.56	3354.6	2821.6	233.8	666.6	105.0	85.3	19.7	165	1.6	0.812	3.8E-6
112	602.04	3243	2265.8	242.1	1072.9	97.4	82.8	14.6	131	1.3	0.850	6.4E-6
113	181.5	3349.7	2999.6	211.1	451.1	115.7	79.3	36.4	285	2.5	0.686	1.4E-6
114	199.58	3651.8	3255.9	234.1	508.5	119.0	82.5	36.5	285	2.4	0.693	1.4E-6
115	182.3	3520	3160.8	243.9	510.3	118.2	87.7	30.5	216	1.8	0.742	2.2E-6
116	300.3	3433.9	2863.1	236.8	693.3	114.0	91.2	22.8	165	1.4	0.800	3.7E-6
117	604.4	3311.2	2302.9	244.9	1102.7	100.1	85.2	14.9	131	1.3	0.851	6.2E-6
118	618.75	3619.8	2586.1	242.2	1121.5	100.2	85.3	15.0	131	1.3	0.851	6.2E-6
119	303.31	3464.9	2927.1	242.3	666.8	106.4	84.0	22.4	165	1.6	0.789	3.7E-6
120	181.73	3350	3010.4	243.7	496.6	112.1	83.5	28.6	216	1.9	0.745	2.2E-6
121	182.84	3772.9	3432.1	211.1	445.1	111.8	76.8	35.0	285	2.5	0.687	1.5E-6
122	188.63	3639.9	3285.2	237.4	481.8	112.8	77.7	35.1	285	2.5	0.689	1.5E-6
123	304.29	3515.7	3002.7	233.1	635.9	101.2	79.4	21.7	165	1.6	0.785	4.0E-6
124	604.92	3399.3	2426.5	238.7	1069.9	96.5	82.4	14.0	131	1.4	0.854	6.6E-6
125	303.87	3551.4	3045.5	241.5	650.6	99.9	80.8	19.1	165	1.7	0.809	4.0E-6
126	183.85	3458.3	3138.9	237.3	485.3	104.2	80.9	23.3	216	2.1	0.776	2.3E-6
127	184.73	3392.8	3036.5	231.4	484.9	115.7	82.3	33.4	285	2.5	0.711	1.5E-6

** Mass of air from cap only

Table A.4 Calculation of Dimensionless Concentration

Run Information

Mannequin Size: Height = 51 inches; Breadth = 14 inches
Gun Type: HVLP Devilbis Spray Gun: MSV-533-4-FF
Gun Setting: Liquid Setting: 2 turns
Air Fan Pattern: 2 turns
Fluid Used: Inland #99 Vacuum Pump Oil
Experimenters: John McKernan and Betty Gatano
Plate Size: Motion: 36" by 36"
No Motion: 24" by 36"
Distance to Plate: 8 inches

Position of Mannequin: 180°:
90°:

Run Number	Date	Mass of Liquid Overspray (m_o) (g/min)	Time (s)	Filter Weight (mg)		Sample Mass (mg)	Sampling flowrate (l/min)	Concentration (mg/m³)	Carton Number	$CUHD/m_o$
				Before	After					
1	8/8/96	18.54	611.78	13.991	13.991	0.000	2.00	0.00	3.1E+5	0.0000
2	8/8/96	21.33	610.58	14.217	14.445	0.228	2.00	11.20	6.1E+5	0.0094
3	8/8/96	24.70	302.64	14.658	20.710	6.052	2.00	599.92	1.4E+6	0.3385
4	8/8/96	28.49	303.25	14.277	19.800	5.523	2.00	546.38	2.6E+6	0.1919
5	8/8/96	30.95	304.41	14.845	20.270	5.425	2.00	534.64	2.8E+6	0.1729
6	8/9/96	15.60	602.65	15.955	17.421	1.466	2.00	72.98	2.9E+5	0.0990
7	8/9/96	20.33	303.92	15.750	16.334	0.584	2.00	57.65	5.7E+5	0.0506
8	8/9/96	25.12	303.12	15.254	16.166	0.912	2.00	90.26	1.3E+6	0.0501
9	8/9/96	29.33	303	15.340	16.442	1.102	2.00	109.11	2.5E+6	0.0372
10	8/9/96	33.53	303.89	15.556	16.715	1.159	2.00	114.42	2.7E+6	0.0342
BLANK	8/9/96									
11	8/10/96	34.47	305.27	15.591	16.058	0.467	2.00	45.89	2.4E+6	0.0146
12	8/10/96	28.17	301.4	15.437	15.935	0.498	2.00	49.57	2.4E+6	0.0176
13	8/10/96	23.56	303.76	15.275	15.566	0.291	2.00	28.74	1.2E+6	0.0170
14	8/10/96	20.71	303.85	15.585	16.115	0.530	2.00	52.33	5.6E+5	0.0451
15	8/10/96	15.04	602.35	15.238	15.883	0.645	2.00	32.12	2.8E+5	0.0452
BLANK	8/10/96									
16	8/10/96	14.98	603.15	15.269	15.278	0.009	2.00	0.45	2.8E+5	0.0006
17	8/10/96	17.74	304.11	14.900	14.962	0.062	2.00	6.12	5.6E+5	0.0062
18	8/10/96	23.21	184.03	14.655	17.732	3.077	2.00	501.60	1.2E+6	0.3012
19	8/10/96	25.75	183.83	14.731	17.717	2.986	2.00	487.30	2.4E+6	0.1894
20	8/10/96	31.13	183.5	14.465	17.514	3.049	2.00	498.47	2.6E+6	0.1603
BLANK	8/10/96									
21	8/14/96	32.12	188.31	14.154	16.896	2.742	2.00	436.83	1.2E+6	0.2879
22	8/14/96	29.50	187.5	14.270	17.374	3.104	2.00	496.64	2.4E+6	0.1731
23	8/14/96	25.47	188.44	14.565	17.656	3.091	2.00	492.09	2.3E+6	0.1987
24	8/14/96	21.88	182.87	13.169	16.105	2.936	2.00	481.65	1.2E+6	0.3068
25	8/14/96	16.54	303.63	13.132	13.051	-0.081	2.00	-8.00	5.3E+5	-0.0088
26	8/14/96	12.72	603.45	14.650	14.583	-0.067	2.00	-3.33	2.7E+5	-0.0055

Table A.4 Calculation of Dimensionless Concentration

Run Information

Mannequin Size: Height = 51 inches; Breadth = 14 inches
Gun Type: HVLP Devilbis Spray Gun: MSV-533-4-FF
Gun Setting: Liquid Setting: 2 turns
Air Fan Pattern: 2 turns
Fluid Used: Inland #99 Vacuum Pump Oil
Experimenters: John McKernan and Betty Gatano
Plate Size: Motion: 36" by 36"
No Motion: 24" by 36"
Distance to Plate: 8 inches

Position of Mannequin: 180°:
90°:

Run Number	Date	Mass of Liquid Overspray (m_e) (g/min)	Time (s)	Filter Weight (mg)		Sample Mass (mg)	Sampling flowrate (l/min)	Concentration (mg/m³)	Carlton Number	CUHD/m_e
				Before	After					
27	8/16/96	14.96	602.9	14.159	15.039	0.880	2.00	43.79	2.9E+5	0.0620
28	8/16/96	20.15	303.36	13.607	13.788	0.181	2.00	17.90	5.7E+5	0.0159
29	8/16/96	25.86	182.34	13.067	13.261	0.194	2.00	31.92	1.3E+6	0.0172
30	8/16/96	30.14	189.91	12.953	13.099	0.146	2.00	23.06	2.4E+6	0.0079
31	8/16/96	33.23	193.04	13.105	13.426	0.321	2.00	49.89	2.6E+6	0.0154
BLANK	8/16/96									
32	8/20/96	16.22	602.94	17.343	17.350	0.007	2.00	0.35	3.0E+5	0.0005
33	8/20/96	19.63	302.27	16.777	16.882	0.105	2.00	10.42	5.9E+5	0.0095
34	8/20/96	21.26	182.31	16.798	16.966	0.168	2.00	27.65	5.9E+5	0.0232
35	8/20/96	26.16	198.84	16.506	16.922	0.416	2.00	62.76	1.3E+6	0.0334
36	8/20/96	26.29	182.1	16.355	16.843	0.488	2.00	80.40	1.3E+6	0.0426
BLANK	8/20/96			16.140	16.176	0.036				

Table A.4 Calculation of Dimensionless Concentration

Run Information

Mannequin Size: Height = 51 inches; Breadth = 14 inches
Gun Type: HVLP Devilbis Spray Gun: MSV-533-4-FF
Gun Setting: Liquid Setting: 2 turns
Air Fan Pattern: 2 turns
Fluid Used: Inland #99 Vacuum Pump Oil
Experimenters: John McKernan and Betty Gatano
Plate Size: Motion: 36" by 36"
No Motion: 24" by 36"
Distance to Plate: 8 inches

Position of Mannequin: 180°:
90°:

Run Number	Date	Mass of Liquid Overspray (m_o) (g/min)	Time (s)	Filter Weight (mg)		Sample Mass (mg)	Sampling flowrae (l/min)	Concentration (mg/m³)	Carlton Number	$CUHD/m_o$
				Before	After					
101	9/14/96	16.27	603.67	15.769	16.373	0.604	2.00	30.02	2.6E+5	0.0390
102	9/14/96	23.27	303	15.407	15.973	0.566	2.00	56.04	5.1E+5	0.0430
103	9/14/96	28.42	182.64	15.630	16.195	0.565	2.00	92.81	1.1E+6	0.0455
104	9/14/96	28.44	182.04	15.424	17.317	1.893	2.00	311.96	2.1E+6	0.1128
105	9/14/96	35.03	183.81	15.212	17.344	2.132	2.00	347.97	2.3E+6	0.1022
BLANK	9/14/96									
106	9/14/96	29.74	182.8	13.680	14.172	0.492	2.00	80.74	1.1E+6	0.0378
107	9/14/96	19.21	302.73	13.745	14.163	0.418	2.00	41.42	5.1E+5	0.0385
108	9/14/96	14.17	603.08	13.678	13.700	0.022	2.00	1.09	2.6E+5	0.0016
BLANK	9/14/96									
109	9/18/96	26.52	182.11	13.613	15.321	1.708	2.00	281.37	1.5E+6	0.1697
110	9/18/96	24.73	222	13.401	15.283	1.882	2.00	254.32	1.1E+6	0.1434
111	9/18/96	19.74	304.56	13.401	14.553	1.152	2.00	113.48	5.2E+5	0.1027
112	9/18/96	14.59	602.04	13.679	13.710	0.031	2.00	1.54	2.7E+5	0.0022
BLANK	9/18/96									
113	9/25/96	36.40	181.5	14.170	15.049	0.879	2.00	145.29	1.6E+6	0.0639
114	9/25/96	36.53	199.58	14.816	14.907	0.091	2.00	13.68	1.6E+6	0.0060
115	9/25/96	30.54	182.3	13.601	14.726	1.125	2.00	185.13	1.2E+6	0.0645
116	9/25/96	22.84	300.3	13.779	13.738	-0.041	2.00	-4.10	5.4E+5	-0.0032
BLANK	9/25/96									
117	9/25/96	14.94	604.4	14.173	15.728	1.555	2.00	77.18	2.7E+5	0.1093
118	9/25/96	14.97	618.75	13.853	16.624	2.771	2.00	134.35	2.7E+5	0.1899
119	9/25/96	22.41	303.31	13.602	14.215	0.613	2.00	60.63	5.4E+5	0.0483
120	9/25/96	28.62	181.73	13.234	14.751	1.517	2.00	250.43	1.2E+6	0.1220
BLANK	9/25/96									
121	10/2/96	35.05	182.84	13.629	15.276	1.647	2.00	270.24	1.5E+6	0.1234
122	10/2/96	35.08	188.63	14.786	16.784	1.998	2.00	317.76	1.5E+6	0.1449
123	10/2/96	21.73	304.29	15.315	16.318	1.003	2.00	98.89	5.1E+5	0.0813
BLANK	10/2/96									

Table A.4 Calculation of Dimensionless Concentration

Run Information

Mannequin Size: Height = 51 inches; Breadth = 14 inches
Gun Type: HVLP Devilbis Spray Gun: MSV-533-4-FF
Gun Setting: Liquid Setting: 2 turns
Air Fan Pattern: 2 turns
Fluid Used: Inland #99 Vacuum Pump Oil
Experimenters: John McKernan and Betty Gatano
Plate Size: Motion: 36" by 36"
No Motion: 24" by 36"
Distance to Plate: 8 inches

Position of Mannequin: 180°:
90°:

Run Number	Date	Mass of Liquid Overspray (m_o) (g/min)	Time (s)	Filter Weight (mg) Before	Filter Weight (mg) After	Sample Mass (mg)	Sampling flowrae (l/min)	Concentration (mg/m³)	Carlton Number	CUHD/m_o
124	10/2/96	14.04	604.92	15.018	15.039	0.021	2.00	1.04	2.6E+5	0.0016
125	10/2/96	19.11	303.87	14.789	15.335	0.546	2.00	53.90	5.1E+5	0.0504
126	10/2/96	23.30	183.85	14.047	15.392	1.345	2.00	219.47	1.1E+6	0.1313
127	10/2/96	33.39	184.73	14.103	15.876	1.773	2.00	287.93	1.5E+6	0.1380

Figure A.1 Air Flow Volume As Function of Square Root of Pressure Drop Across Orifice

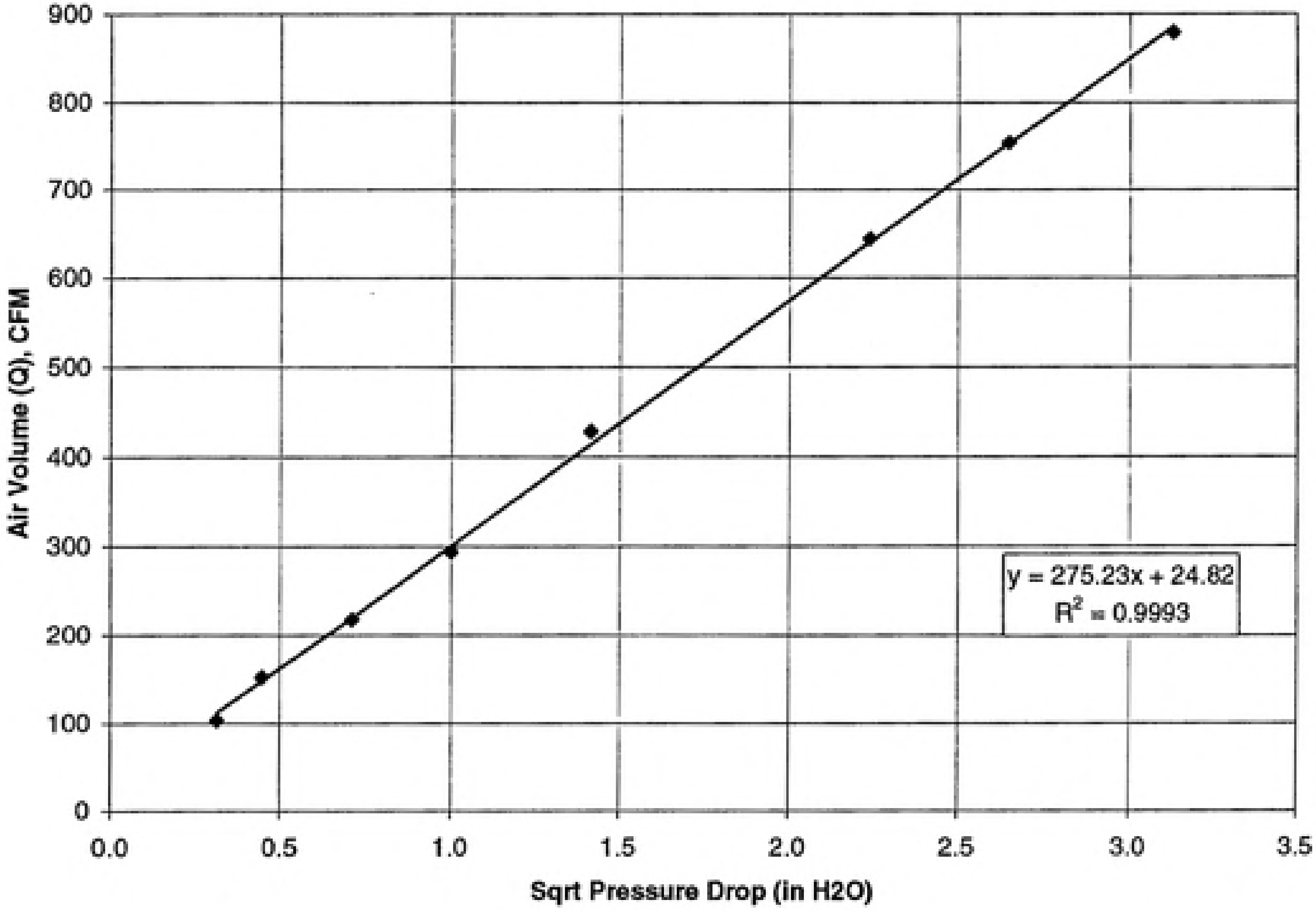


Figure A.2 Calibration of Hot-Wire Anemometer

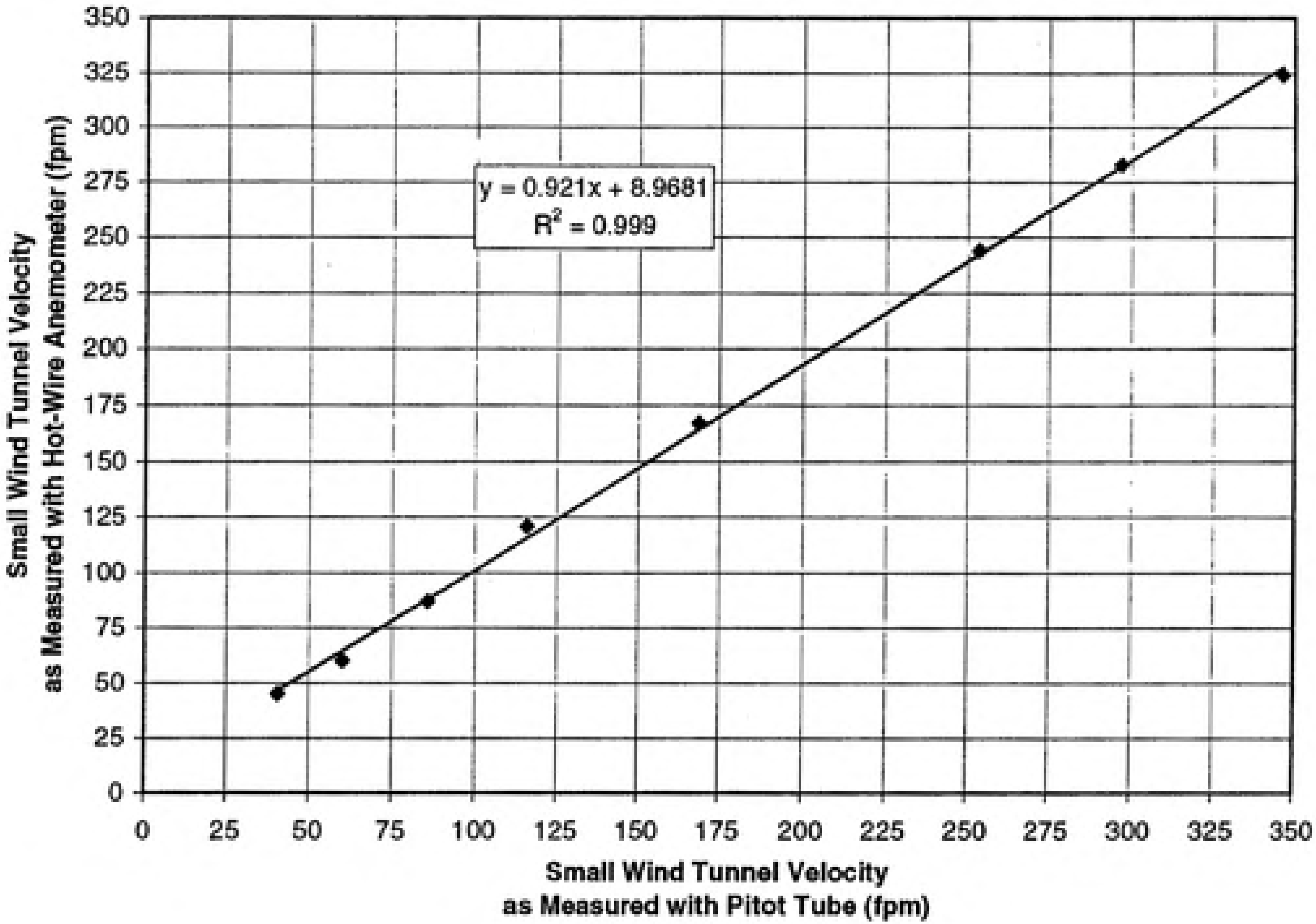


Figure A.3 Calibration of Wind Tunnel Using Hot Wire Anemometer

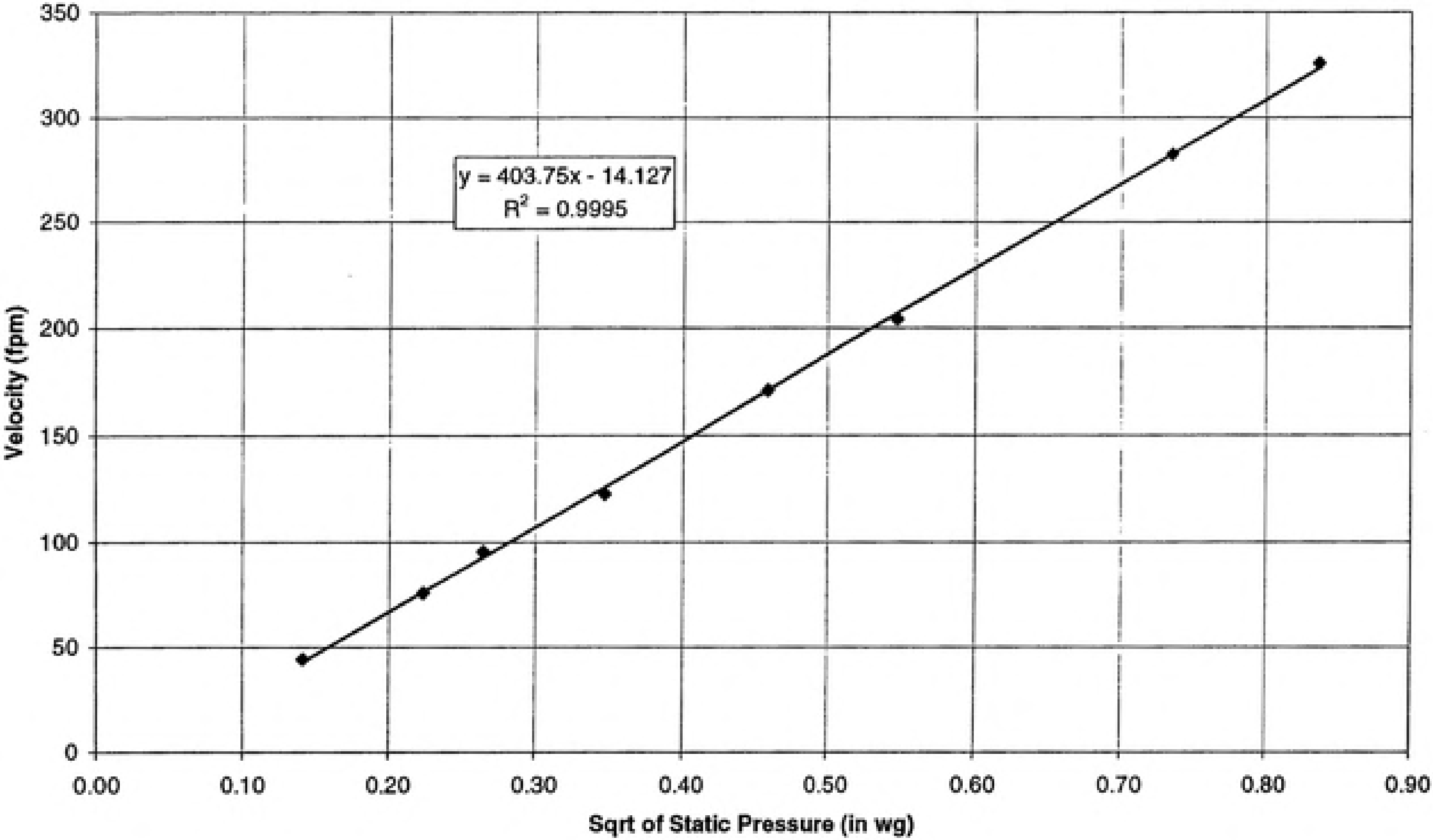
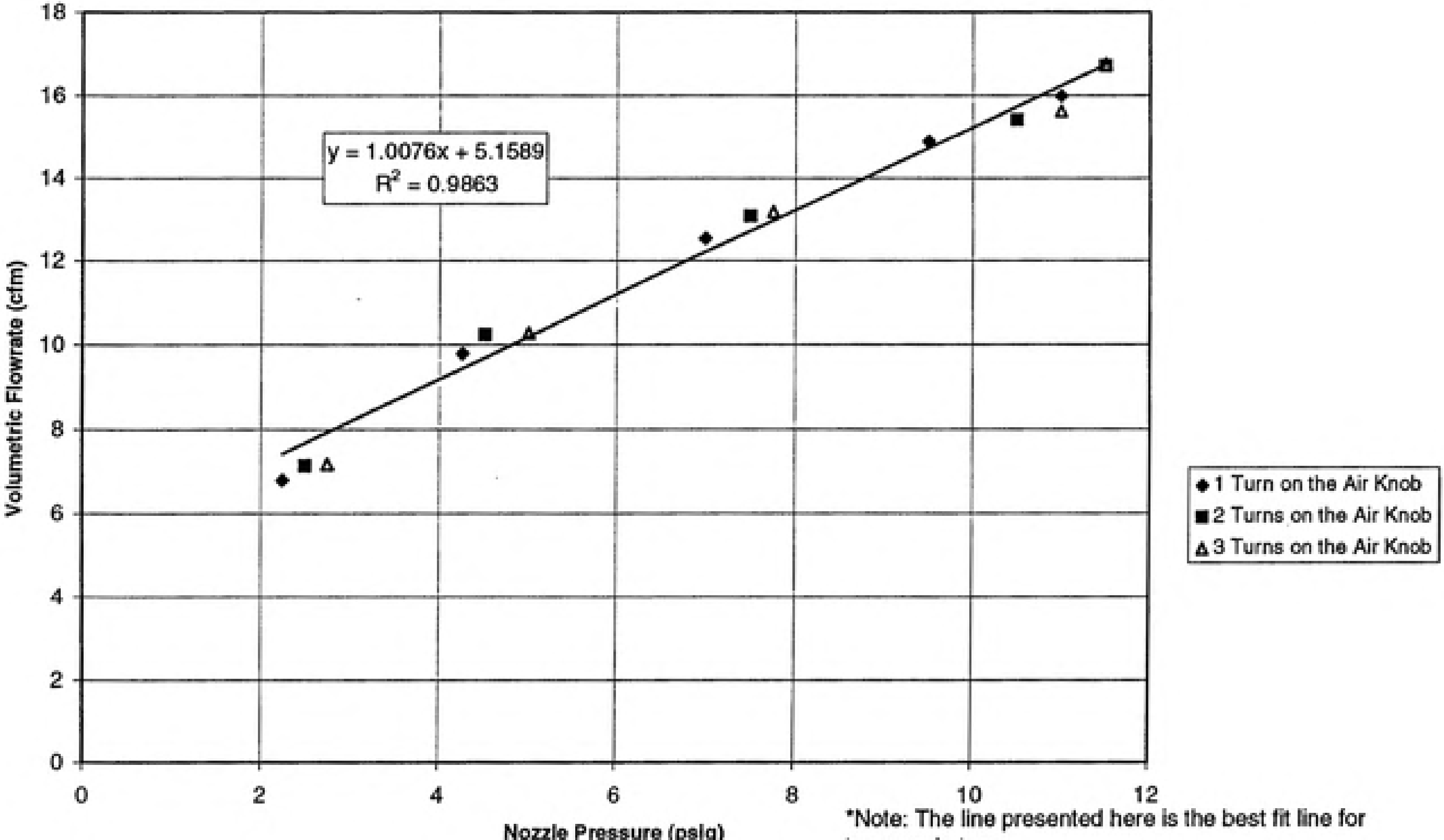


Figure A.4 Air Volumetric Flowrate from the HVLP Gun as a Function of Fan Pattern and Nozzle Pressure



*Note: The line presented here is the best fit line for two nozzle turns.

Figure A.5 Viscosity of Vacuum Pump Oil as a Function of Temperature

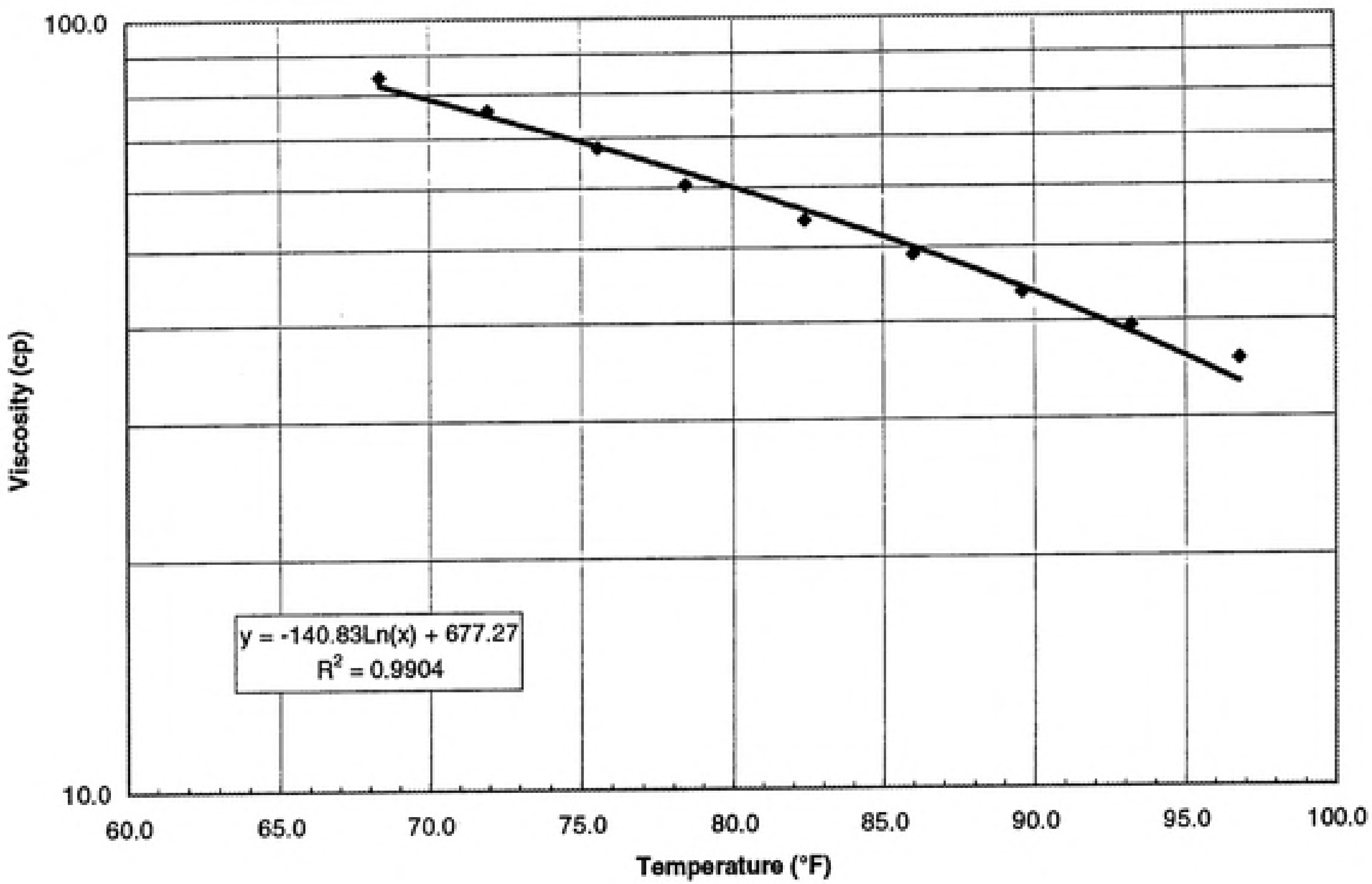
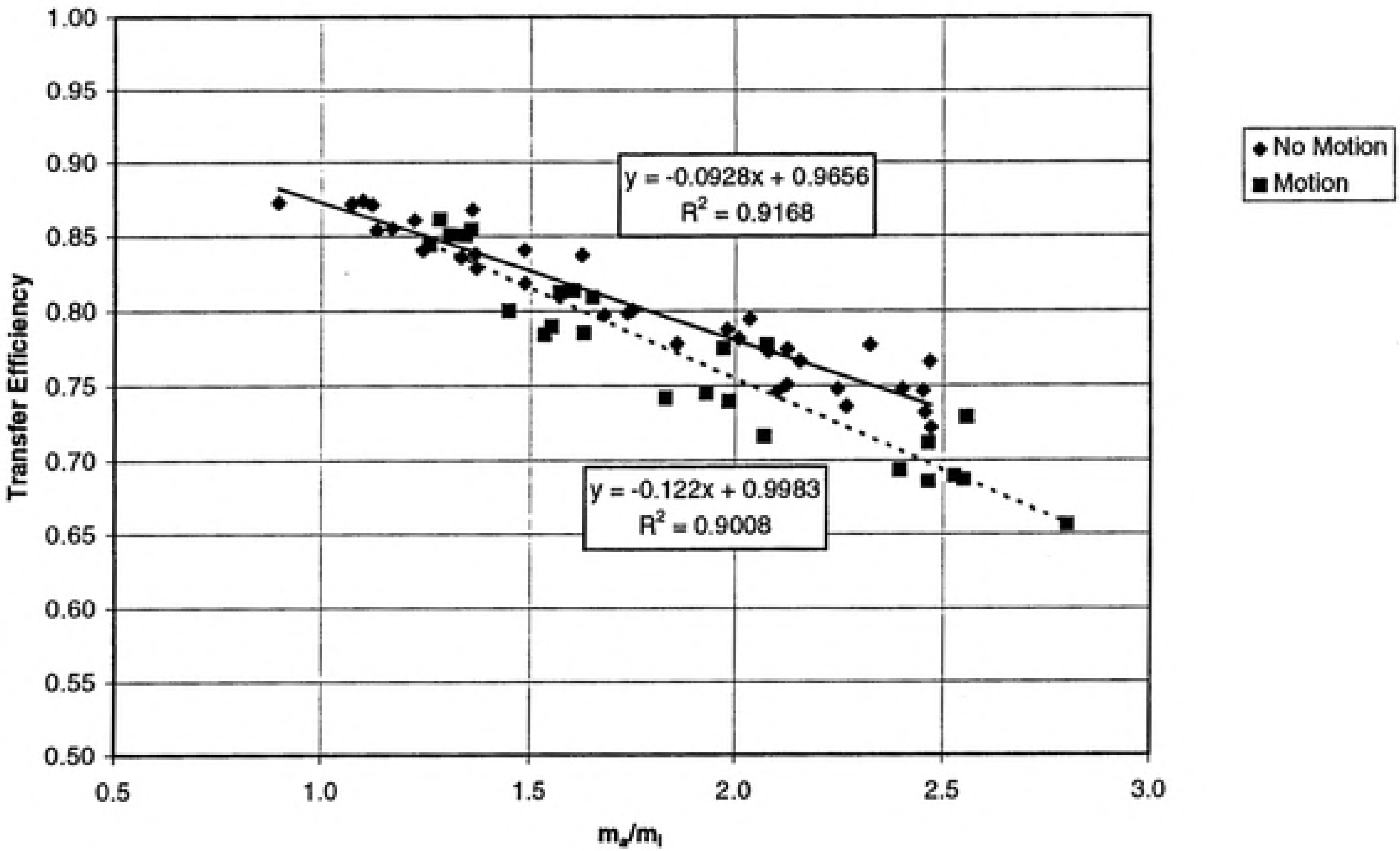


Figure A.6 Transfer Efficiency as a Function of m_a/m_l



8.0 Appendix B:

Additional Materials

Appendix B:

Additional Materials

B.1. Calculating Task-Representative Carlton Numbers

Before analyzing the data for the experiments, it was considered important to determine the range of dimensionless pressure terms which would most likely correspond to real applications in the field. This was considered because the ultimate purpose of the current model is its use in predicting personal breathing zone concentrations (exposures) in the field. Breathing zone concentrations can be predicted for particular spraying tasks using the current model, when only the Carlton number is known. Therefore, Table B.1 was created to determine the high and low range of Carlton numbers (p_aH/μ_lU) which could be expected in normal HVLP applications.

Table B.1. Calculation of Task Representative Carlton Numbers:

U	p_a	H	μ_l		Unit p_aH/μ_lU Upper	Unit p_aH/μ_lU Lower
75	4	5	40		0.021667	0.002667
90	6	5.5	45		0.011852	0.006286
105	8	6	50			
125	10	6.5	60			

Multiplier for calculating dimensionless pressure term = 4.18E+8

Dimensionless p_aH/μ_lU Upper	Dimensionless p_aH/μ_lU Lower
9.0×10^6	1.1×10^6
4.9×10^6	2.6×10^6

It can be seen in the table for common HVLP use, the Carlton numbers vary from 1.1 x 10^6 at the lowest values and 9.0 x 10^6 at the highest values. The lowest value from this table is referred to as the task representative Carlton number. The dimensionless concentration above the task representative Carlton number in each of the orientation equations are set as constants to aid in the estimation of exposure.

B.2. Overspray Generation Rate

The overspray generation rate, m_o, is a measure of the total mass of overspray entrained in the freestream available for exposure in a given time. The m_o term was calculated using the measured transfer efficiency (t_e) at the nozzle pressure used, the mass of the liquid sprayed, and the time over which spraying occurred (t_s) in the formula below:

$$m_o = (1 - t_e) \times \left(\frac{\text{mass of liquid sprayed}}{t_s} \right)$$

The mass of the liquid sprayed from the gun minus the mass of the liquid transferred to the workpiece, in g/min, also gives the overspray generation rate. The transfer efficiency (t_e) is equal to the amount of the liquid transferred to the workpiece divided by the amount of the liquid sprayed from the gun (m_l). This term is dimensionless and can be used as another possible predictor of exposure, in place of the dimensionless breathing zone concentration term. This was the focus of Gatanos' work done jointly in this study.

B.3. Dimensionless Nozzle Pressure Term

The dimensionless nozzle pressure term, or Carlton number, was found by multiplying the measured nozzle pressure (p_n) of the gun at the cap in psig, by the height (H) of the mannequin in ft, and dividing this by the product of the freestream velocity (U) measured in the tunnel in fpm, multiplied by the viscosity of the oil (μ_l) in cp.

$$\frac{p_n H}{\mu_l U} = \frac{\text{droplet transport}}{\text{droplet transfer}}$$

And also, as you can see, the Carlton number incorporates the relative contributions of the droplet transfer and transport processes in producing an exposure. This is what makes the dimensionless nozzle pressure so important to this model for spray painting. Once values for the Carlton number were obtained, a unit conversion factor of 4.1759 x 10^8 (cp · fpm/psig · ft) was applied. After some manipulation it can be seen that the units cancel.

B.4. Calculating Concentrations

B.4.1. Average Breathing Zone Concentration

Concentration is determined by considering that the worker's average breathing zone concentration (C) is a function of the variables identified in the conceptual model. Representing the dependence as an equation:

$$C = \phi\left(m_o, p_a, \mu_l, \frac{m_a}{m_l}, \text{U, H, D, orientation} \right)$$

Numerical calculation of the average breathing zone concentration was more straightforward. Total contaminant concentration for each run was calculated using the filter weight change after sampling in mg (m_s), and dividing by the product of the volume sampled through the filter in liters per minute (v_s), and the run time for the sample in seconds (t_s):

$$C = \frac{m_s}{v_s t_s}$$

Once this value was obtained, it was transformed to the units mg/m^3 by the use of a conversion factor of 6.0×10^4 (L/min · s)/m^3.

B.4.2. Dimensionless Breathing Zone Concentration

The dimensionless breathing zone concentration was defined by the Carlton model. Dimensional analysis done by Carlton provides the following dimensionless representation of the model:

$$\frac{CUHD}{m_o} = \Phi\left(\frac{m_a}{m_l}, \frac{p_n H}{\mu_l U}, \text{orientation}\right)$$

The model indicates the concentration group $CUHD/m_o$ depends on worker orientation to the freestream and two other nondimensional groups; the air-to-liquid mass flow ratio m_a/m_l and the dimensionless pressure group p_nH/μ_lU. The model strongly suggests that $CUHD/m_o$ is a function of the quantity p_nH/μ_lU and worker orientation. This makes the comparison of the two nondimensional groups of pressure and concentration more significant. To make the values dimensionless, it is necessary in calculating the data to use a factor to relate volume units. For the data, 3.048×10^{-7} ft^3/m^3 was used.

B.5. Statistical Analysis

Statistical analysis was performed on the data obtained in this experiment for two reasons:

- To express the relationships between dimensionless breathing zone concentrations and dimensionless pressure terms.
- To determine the statistical significance of the data.

The first set to be analyzed was the no motion 90 and 180 degree position data. This data, with standard deviations about the mean, is displayed in Figure 3. First looking at the 90° position data, linear regression with a best fit equation was determined:

$$\frac{CHUD}{m_o} = 3 \times 10^{-7}\left(\frac{p_n H}{\mu_1 U}\right) - 0.1336 \qquad r^2 = .93$$

The formula was applied to data below the constant concentration achieved at Carlton numbers > 1.3 x 10^6. The constant concentration for Carlton numbers > 1.3 x 10^6 was = 0.232.

The following set to be analyzed was the no motion 180° position data. This data, with standard deviations about the mean, is also displayed in Figure 3.

Regression analysis with a best fit equation was determined for the 180° position. The equation used in past research by Carlton gave a better fit than the new data analysis could provide. Therefore, the formula for the best fit line was:

$$\frac{\text{CHUD}}{m_o} = 3.23 \times 10^{-2} \exp\left(-1.94 \times 10^{-7} \frac{p_a H}{\mu_1 U}\right) \quad r^2 = .95$$

This formula gives a best fit throughout the range of data. Dispite this goodness of fit, values greater than the task representative Carlton number were once again expressed as a constant concentration. For Carlton numbers > 1.1 x 10^6, the constant concentration was given as 0.0281.

The motion data was last to be considered. Both orientations with motion produced very similar results. One statistical tests were performed on the data for both orientations to determine significance. An analysis of covariance was used to test if the position of the worker effected dimensionless breathing zone concentration in the range representative of a spray painting task. The ANCOVA analysis was done using the SAS program and is included in Table B.2. Analysis provided support to the hypothesis that the 90° and 180° orientation data were not significantly different in the motion experiment. Since there was no positional effect, no formulae were used to explain the relation between dimensionless concentration and dimensionless pressure terms for the individual orientations. Instead, an average of all the data points in the task representative Carlton number range (Carlton numbers > 1.1 x 10^6) was taken.

This produced an average dimensionless breathing zone concentration for motion in either position of 0.102. The motion data, with standard deviations about the mean, is displayed in Figure 5.

B.6. Sources of Error

B.6.1. Gravimetric Analysis:

The gravimetric analysis using the Cahn 27 automatic electrobalance had a ±0.005% error associated with it due to the accuracy of the electrical range of the scale. The scale precision allows measurement of changes in weight of 0.1 μg in a sample.

B.6.2. Breathing Zone Concentration (C or BZC):

The NIOSH 0500 method (particulates not otherwise regulated, total) was used to determine airborne particulate concentration in this experiment. The accuracy of the method was given as ±11.04% over a 20 mg/m^3 range. Overall precision of the analysis was limited to 56 μg/m^3. A bias of 0.01% was also associated with the use of the method.

B.6.3. Measuring Distances, Height and Width (H, D):

Accuracy of measure with retractable measuring tapes and rulers were to 1/16 of one inch (0.15875 cm).

B.6.4. Flow Rate (U):

The Alnor thermoanemometer was accurate at measuring air velocities within ±3% in the range of operation for these experiments. The equipment was limited to an accuracy of ±2 fpm in optimal circumstances. The resolution of the equipment was within 1 fpm from the value displayed.

B.6.5. Gun Pressure (p_n):

Pressure readings for the gun cap pressures were within 1 psig of the actual value. This reading error is associated with the resolution of the gauge.

B.6.6. Overspray Generation Rate (m_0):

Error for mass measurement of m_0 associated with the use of a Mettler PM34-K was associated with the resolution of the scale (readability) which is 1g / 0.1g. Weighing range of the scale is 0 to 32,000g, and repeatability of the scale is ≤ 0.3g per 0.1g. Linearity for this scale is given as less than or equal to ± 0.5g per ± 0.2g. Time was also a source of error for this calculation. Time measurements, because of human error, were assumed to be within ± 1.6%.

B.6.7. Viscosity (μ_l):

The falling ball viscometer had a 'tolerance range' for error. This tolerance range involved only human time measurement error which is ± 1.6% throughout the experiment.

B.6.8. Mass of Air (m_a):

Pressure readings for the gun cap pressures were within 1 psig of the actual value. This reading error is associated with the resolution of the gauge. Density of the air was calculated using the barometric pressure on the day these calibrations were performed.

B.6.9. Mass of Liquid (m_l):

Error for mass measurement of m_l associated with the use of a Mettler PM34-K was associated with the resolution of the scale (readability) which is 1g / 0.1g. Weighing range of the scale is 0 to 32,000g, and repeatability of the scale is ≤ 0.3g per 0.1g. Linearity for this scale is given as less than or equal to ± 0.5g per ± 0.2g. For a more detailed error analysis, see Carlton [1].

B.7. Sample Calculations (Run Number 1)

B.7.1. Freestream Velocity (U)

$$\text{Hot Wire Anemometer (fpm)} = 403.75\sqrt{SP} - 14.127$$

$$= 403.75\sqrt{0.05} - 14.127$$

$$= 76.154 \text{ fpm}$$

$$\text{Freestream Velocity (fpm)} = 1.0848\ (\text{Hot Wire Anemometer}) - 9.5625$$

$$= 1.0848\ (76.154) - 9.5625$$

$$= 73.05 \text{ fpm}$$

B.7.2. Viscosity (μ_l)

Viscosity (cp) = 678.95 exp (-0.0306 * T(°F))

= 678.95 exp (-0.0306 * 81)

= 68.412 cp

B.7.3. Liquid Mass Sprayed (m_l)

$$m_l\,(\text{g/min}) = \frac{\text{Container Mass (Grams Before)} - \text{Container Mass (Grams After)}}{\text{Run Time (Seconds)} \cdot \text{Minutes}/60\ \text{Seconds}}$$

$$= \frac{3400.9 - 2986.8}{183.97 \cdot 1/60}$$

= 135 g/min

B.7.4. Liquid Mass Transferred

Mass Transferred (g/min) =

$$= \frac{\text{Trough Mass (Grams Before)} - \text{Trough Mass (Grams After)}}{\text{Run Time (Seconds)} \cdot \text{Minutes}/60\ \text{Seconds}}$$

$$= \frac{551.9 - 223.8}{183.97 \cdot 1/60}$$

= 107 g/min

B.7.5. Mass of Liquid Overspray

Mass of Liquid Overspray (g/min) = m_l (g/min) - Liquid Mass Transferred (g/min)

=135.1 - 107

= 28.1g/min

B. 7.6. Mass of Air (m_a)

Volumetric Flow Rate (ft^3/min) = 1.0076 (p_n (psig) - Cap Pressure (psig)) + 5.1589

g/min = ft^3/min x (0.075 lb/ft^3) x (4.3359 x 10^2 g/lb)

= 34 (Volumetric Flow Rate) (0.5)

= 34 (16.75) (0.5)

= 284.7 g/min

B. 7.7. Dimensionless Pressure Term (Carlton number)

$$\text{Carlton number} = \frac{4.14 \times 10^{8} \cdot (p_{n}\,(\text{psig}) - \text{Cap Pressure (psig)}) \cdot H\,(\text{ft})}{\mu_{1}(\text{cp}) \cdot U\,(\text{fpm})}$$

$$= \frac{4.14 \times 10^{8} \cdot (6.5) \cdot (4.25)}{(68.41) \cdot (73)}$$

$$= 2.29 \times 10^{6}$$

B. 7.8.8 Concentration (C)

$$C\,(\text{mg/m}^3) = 60000\,\frac{\text{Sample Filter Mass (mg)}}{\text{Sampling Rate (l / min)} \cdot (\text{Sampling Time (s)})}$$

$$= 60000\,\frac{0.146}{2 \cdot (189.91)}$$

$$= 23.06\ \text{mg/m}^3$$

B. 7.8.9. Dimensionless Concentration

$$\frac{CUHD}{m_0} = 2.8317 \times 10^{-5}\,\frac{C\,(\text{mg / m}^3) \cdot H\,(\text{ft}) \cdot U\,(\text{fpm}) \cdot D\,(\text{ft})}{m_0\,(\text{g / min})}$$

$$= 2.8317 \times 10^{-5} \left(\frac{4.25 \cdot 1.17 \cdot 73 \cdot 217.86}{28}\right)$$

$$= 0.07998$$

B. 7.8.10. Mass of Air to Mass of Liquid Ratio (m_a/m_l)

$$m_a/m_l = \frac{284.7}{135.1}$$

$$= 2.1$$

B. 7.8.11. Sample Filter Mass

Filter Mass (mg) = Filter After (mg) - Filter Before (mg)

= 14.741 - 13.405

= 1.336 mg

Table B.2: ANCOVA analysis of the motion data

Class Level Information

Class	Levels	Values
ORIENT	2	90 180

Number of observations in data set = 14
General Linear Models Procedure

Dependent Variable: CON

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	0.00561686	0.00280843	1.29	0.3137
Error	11	0.02393719	0.00217611		
Corrected Total	13	0.02955406			

R-Square	C.V.	Root MSE	CON Mean
0.190054	45.81752	0.04664878	0.10181429

Source	DF	Type I SS	Mean Square	F Value	Pr > F
ORIENT	1	0.00384209	0.00384209	1.77	0.2108
CNUM	1	0.00177478	0.00177478	0.82	0.3858

Source	DF	Type III SS	Mean Square	F Value	Pr > F
ORIENT	1	0.00528479	0.00528479	2.43	0.1474
CNUM	1	0.00177478	0.00177478	0.82	0.3858

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		0.0282812759 B	0.41	0.6919	0.06951256
ORIENT	90	0.0431861897 B	1.56	0.1474	0.02771223
	180	0.0000000000 B	.	.	.
CNUM		0.0000000384	0.90	0.3858	0.00000004

NOTE: The X'X matrix has been found to be singular and a generalized inverse was used to solve the normal equations. Estimates followed by the letter 'B' are biased, and are not unique estimators of the parameters.

Least Squares Means

ORIENT	CON LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	Pr > |T| H0: LSMEAN1=LSMEAN2
90	0.12957684	0.02174421	0.0001	0.1474
180	0.08639065	0.01591827	0.0002	

OBS	_NAME_	ORIENT	LSMEAN	STDERR	NUMBER	COV1	COV2
1	CON	90	0.12958	0.021744	1	0.00047281	-.00002088
2	CON	180	0.08639	0.015918	2	-.00002088	0.00025339

General Linear Models Procedure

Class Level Information

Class	Levels	Values
ORIENT	2	90 180

Number of observations in data set = 14

General Linear Models Procedure

Dependent Variable: CON

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	0.00384209	0.00384209	1.79	0.2054
Error	12	0.02571197	0.00214266		
Corrected Total	13	0.02955406			

R-Square	C.V.	Root MSE	CON Mean
0.130002	45.46407	0.04628892	0.10181429

Source	DF	Type I SS	Mean Square	F Value	Pr > F
ORIENT	1	0.00384209	0.00384209	1.79	0.2054
IND1	0	0.00000000	.	.	.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
ORIENT	0	0	.	.	.
IND1	0	0	.	.	.

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		0.0894666667 B	5.80	0.0001	0.01542964
ORIENT	90	0.0345733333 B	1.34	0.2054	0.02581873
	180	0.0000000000 B	.	.	.
IND1		0.0000000000 B	.	.	.

NOTE: The X'X matrix has been found to be singular and a generalized inverse was used to solve the normal equations. Estimates followed by the letter 'B' are biased, and are not unique estimators of the parameters.

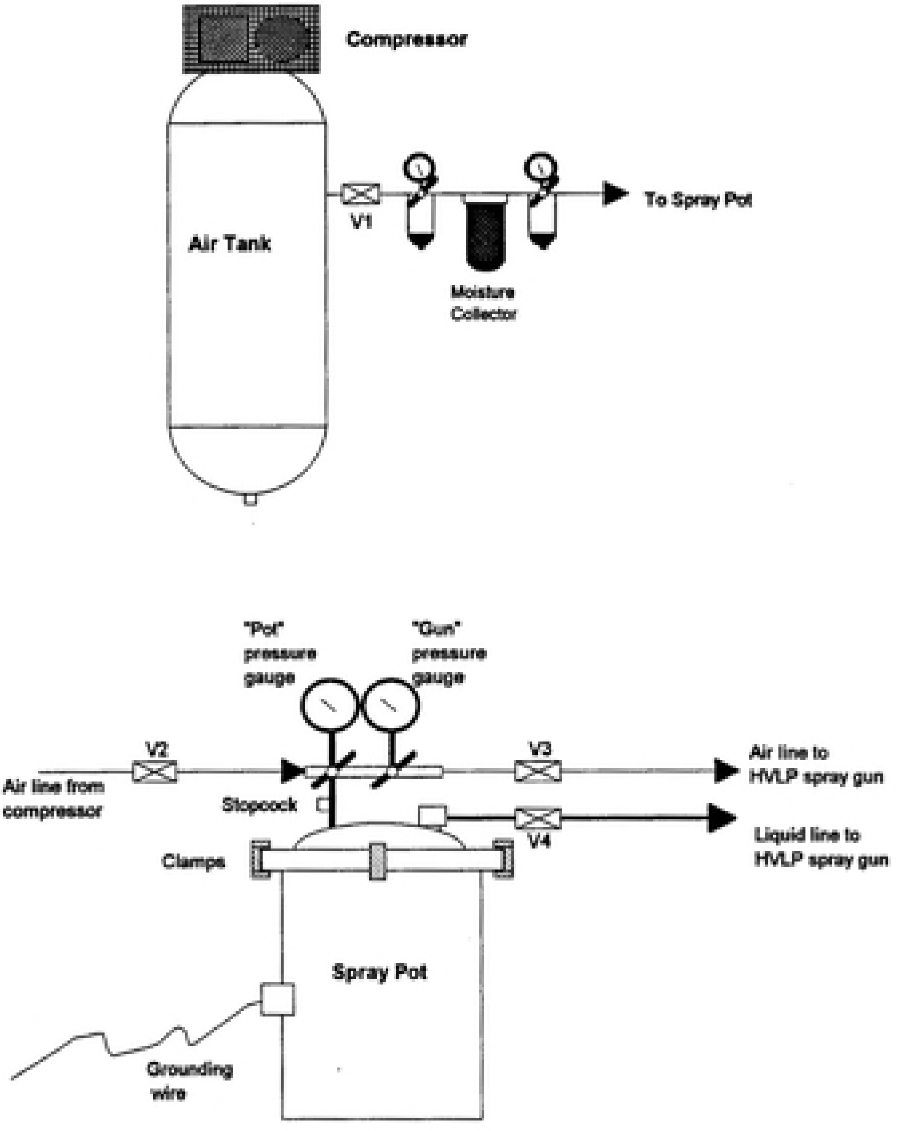


Figure B.3. Schematic of Compressor and Spray Pot Systems

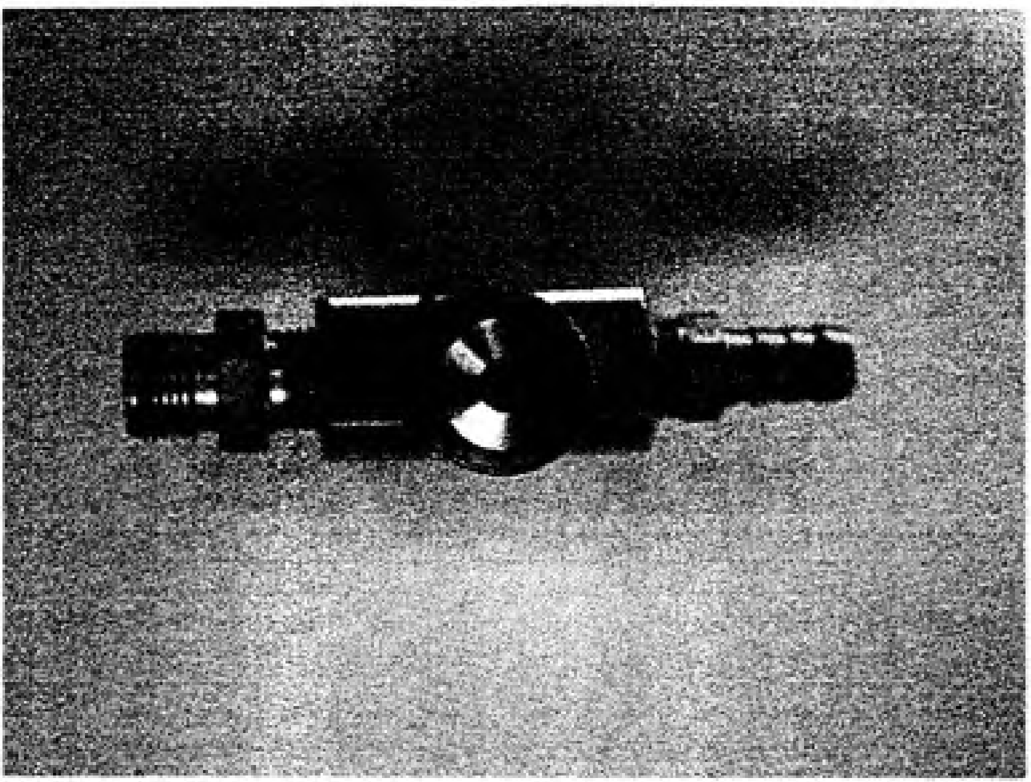


Figure B.4: 1/4 J High Pressure Spray Nozzle

Figure B.5: High Volume-Low Pressure Spray Gun

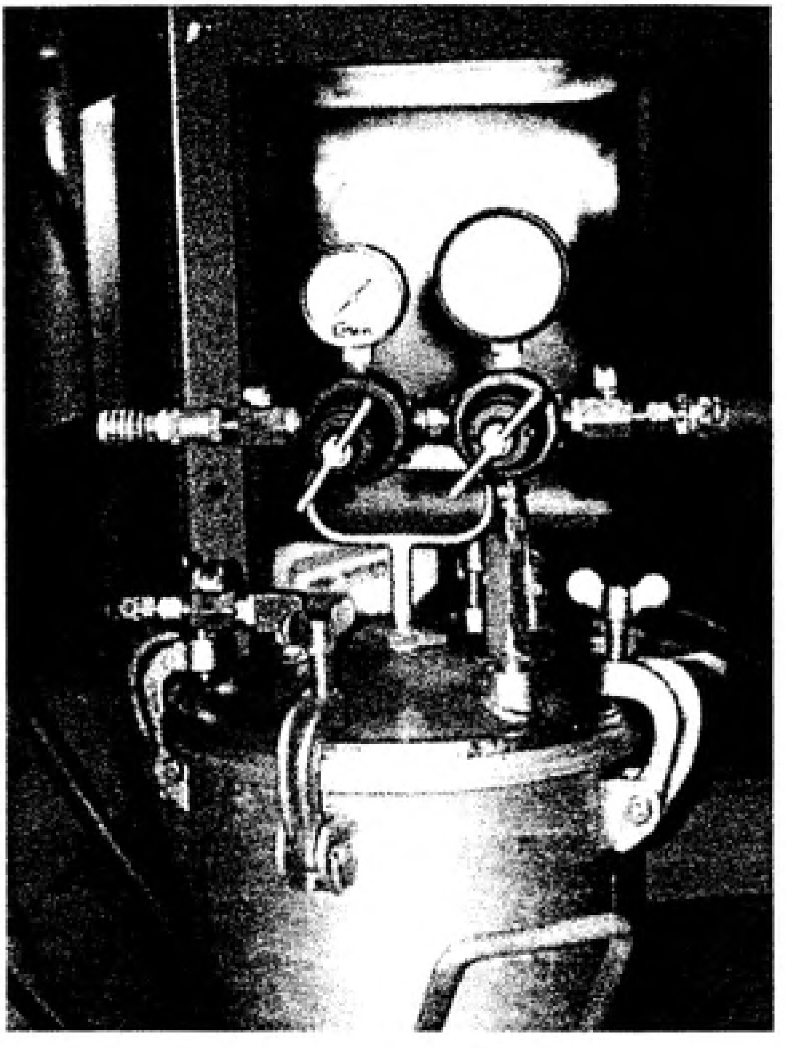


Figure B.6: Complete Pressurized Paint Vessel

Figure B.7: Laboratory Equipment Setup

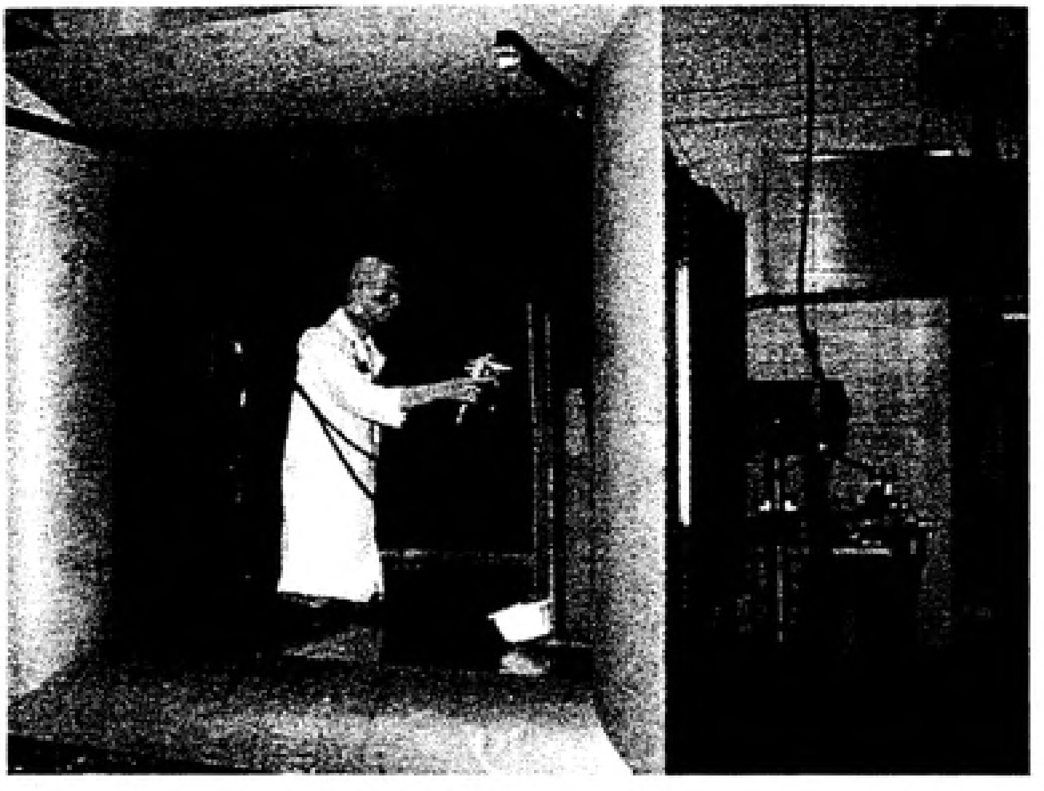


Figure B.8: Mannequin in 90° Orientation

Figure B.9: Mannequin in 180° Orientation

INLAND

INLAND VACUUM INDUSTRIES
85 Howard Avenue • P.O. Box 373
Churchville, NY 14428-0373
716-293-3330 • 800-962-8099
FAX: 716-293-3093

INLAND 99

SPECIFICATIONS

VAPOR PRESSURE	@ 25 C	2×10^{-4} torr
VISCOSITY	@ 40 C	28 cSt (134SUS)
	@100 C	4.5 cSt (41SUS)
BOILING POINT	@ .01 torr	112 C (234 F)
POUR POINT		-15 C (5 F)
FLASH POINT		199 C (390 F)
FIRE POINT		221 C (430 F) *
DENSITY		0.86 g/ml

MATERIAL SAFETY DATA SHEET

MANUFACTURER: Inland Vacuum Industries
35 Howard Ave
Churchville NY 14428

EMERGENCY TELEPHONE
DAYS: 716-293-3330
EVENINGS: 800-644-4829 X6186

PREPARED BY: Marc C. Tarplee DATE: 01-23-95

****

SECTION ONE: GENERAL INFORMATION

****

PRODUCT CODE: 462014
PRODUCT NAME: **Inland 99- Liquid Ring Pump Seal Fluid**

NFPA RATING

FLAMMABILITY	1
HEALTH HAZARD	0
REACTIVITY	0
SJPECIAL HAZARD	NONE

CAS NUMBER: 64742-65-0
CHEMICAL FORMULA: $(CH_2)_n$ 20 =< n =< 40
GENERIC NAME: Solvent refined neutral paraffinic oil

****

SECTION TWO:REGULATED INGREDIENTS
(29 CFR 1910.1200)

****

REGULATED MATERIALS AT CONCENTRATION
OF 1 % (WT) OR GREATER

NO HAZARDOUS INGREDIENTS. MATERIAL IS
100 % NEUTRAL PARAFFINIC OIL. MATERIAL
HAS BEEN SUBJECT TO SEVERE SOLVENT REFINING

****

SECTION THREE: HEALTH HAZARDS

****

POSSIBLE ENTRY ROUTES: Ingestion, inhalation of oil mists

TARGET ORGANS:

EFFECTS OF OVEREXPOSURE

ACUTE EFFECTS: Exposure to oils mists may cause nausea and eye irritation. Detailed studies have not been made, but material is not expected to be dermatitic or a sensitizer.

CHRONIC EFFECTS: Unknown.

FIRST AID PROCEDURES: Skin - wash with soap and water. Eyes - flush with water. Contact a physician! Ingestion: Contact a physician! Small amounts in mouth may be washed out.

REFERENCES:

****

SECTION FOUR: FIRE AND EXPLOSION DATA

****

FLASH POINT: > 213 C METHOD USED: Cleveland Open Cup

EXPLOSIVE LIMITS LOWER. Unknown

UPPER: Unknown

EXTINGUISHING MEDIA: Water fog, chemical foam or carbon dioxide.

SPECIAL FIREFIGHTING PROCEDURES: Wear breathing gear when fighting fires in enclosed spaces; incomplete combustion of this material produces carbon monoxide!

UNUSUAL FIRE AND/OR EXPLOSION HAZARDS: None

****

SECTION FIVE: PHYSICAL PROPERTIES

****

PHYSICAL STATE: Liquid
VAPOR PRESSURE: < .001 Torr @ 25C BOILING POINT: > 200 C
EVAPORATION RATE (ether = 1): Nil
VAPOR DENSITY: approximately 14 WT % VOLATILES: Nil
SPECIFIC GRAVITY: 0.86 VISCOSITY: 28 cst @ 40 C
SOLUBILITY IN WATER: Nil
APPEARANCE: Pale yellow, viscous liquid with faint petoleum odor.

****

SECTION SIX: REACTIVITY

****

STABILITY: Material is stable

CONDITIONS TO AVOID: Continuous exposure to temperatures > 200 C

INCOMPATIBILITY (MATERIALS TO AVOID): Strong oxidizers

HAZARDOUS DECOMPOSITION PRODUCTS: Incomplete combustion may produce carbon monoxide.

****

SECTION SEVEN:RELEASE PROCEDURES

****

PROCEDURE TO BE FOLLOWED IN EVENT OF RELEASE: Small spills may be wiped up with a rag. Large spills should be picked up immediately with an absorbent.

PROCEDURES FOR PROPER WASTE DISPOSAL: Proper waste disposal procedures are dependent on the product's end-use. Check applicable Federal, State and Local covering treatment, storage and disposal of your process effluents.

****

SECTION EIGHT:SPECIAL PROTECTION

****

RESPIRATORY PROTECTION: See notes on ventilation below.
PROTECTIVE GLOVES: Yes - made of oil-impermeable rubber
SAFETY GLASSES/GOGGLES: Yes - glasses should have side shields
OTHER PROTECTIVE EQUIPMENT: None should be required under normal use.

VENTILATION US Gov't 8 hr TWA limit for exposure to oil mists is 5 mg per cubic meter
LOCAL EXHAUST: As required to meet limit shown above
MECHANICAL EXHAUST: As required to meet limit shown above
OTHER REQUIREMENTS:

****

SECTION NINE:SPECIAL PRECAUTIONS

****

SPECIAL HANDLING PRECUATIONS: None

SPECIAL STORAGE PRECAUTIONS: None

ADDITIONAL INFORMATION. NFPA Class III B material

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14 Kwok, K.C.: A Fundamental Study of Air Spray Painting. Ph.D. Thesis U. of Minnesota, MN (1991).

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16 Mark, D.; Vincent, J. H.: Entry Characteristics of Practical Workplace Aerosol Samplers in Relation to the ISO Recommendations. **Ann. Occup. Hyg.** 34 (3) (1990).

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