DISSERTATION

INCREASING USE OF RESPIRATORS THROUGH A LEADERSHIP-BASED INTERVENTION

Submitted by

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY STEVEN M. THYGERSON ENTITLED INCREASE COMPLIANCE WITH RESPIRATOR USE REQUIREMENTS THROUGH A LEADERSHIP-BASED INTERVENTION BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

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ABSTRACT OF DISSERTATION

INCREASING USE OF RESPIRATORS THROUGH A LEADERSHIP-BASED INTERVENTION

This dissertation presents a multifaceted leadership-based intervention focused on increasing rotogravure printing press operators' use of respirators and safe work practices. The research followed a leadership-based intervention model in which first line supervisors, managers and team leaders were utilized to drive the change. In addition to the use of leadership, the intervention included employee-conducted air sampling to communicate toluene concentration levels inside the printing press enclosures.

To measure certain determinants of respirator use, a pre- and post-intervention questionnaire was used. The pre-intervention questionnaire focused on each employee's past use of respirators and future intentions to use a respirator when required according to company expectations. The post-questionnaire was aimed at evaluating how a leadership-based intervention affected employees' attitudes towards respirator use. Six weeks of video monitoring was the observation tool used to verify pre-intervention use of respirators and safe work practices compared to post-intervention use of respirators and safe work practices.

Although the trend toward increased use of safe work practices was observed, intentions toward increased respirator use were not predictive of behavior (r = -.161, p>.05). While no employee was observed using a respirator during the six-week study, utilization of safe work practices aimed at protection employees from high concentrations of organic solvents increased (p<.027). It was concluded that use of employee-conducted air monitoring might have been the most effective tool at communicating the risk of organic solvent exposure and the importance of avoiding exposure by using a respirator or adhering to safe work practices.

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1.0 INTRODUCTION

Federal regulation mandates that workers be protected from high exposures to hazardous chemicals. The preferred control methods are elimination, substitution and engineering or administrative controls. The use of personal protective equipment must be used to control hazardous exposure to workers when other controls are not possible. In some instances, respiratory protection equipment may be required. The Occupational Safety and Health Administration (OSHA) regulation 29 CFR 1910.134 requires employers to have a respiratory protection program that includes provisions for proper respirator selection, written protocols, worker training and medical surveillance when respirator use is required.[1] Fewer incidences of worker accidents and illnesses, reduced regulatory compliance costs, and improved productivity may all result from a well-designed respiratory protection program.[2]

However, pertinent industrial hygiene and safety literature contained many references to the inherent difficulties in changing worker behavior in relation to the wearing of personal protective equipment.[3] This can be true for required respirator use where no requirements existed prior to industrial hygiene exposure assessments. Additionally, a recent survey conducted by the Bureau of Labor Statistics indicated that many companies might be in violation of respirator requirements.[4] The hierarchy of factors affecting the use of respiratory protection equipment may include knowledge, beliefs and attitudes, physical and psychological effects, and external influences.[5] The beliefs that influence use of respirators may differ by workplace.

Study results supported that respirator use is a social behavior and that the perceived attitudes of others in a particular workplace may influence respirator use. It may therefore be useful to include supervisors and management personnel as active participants in any training or intervention program that focuses on improved respirator use. Results of a study suggested that for intervention strategies to be most effective, a multidimensional focus on several different determinants of respirator use be utilized. Training efforts that attempt to change worker's beliefs may be useful, but alone may have limited success.[6]

Research needed to be conducted to determine if such multidimensional intervention efforts changed safety behaviors and improved respirator use. This study assessed whether the use of video monitoring for frequency and duration estimates of the use of respirator or adherence to safe work practices, employee-conducted air sampling, and leadership-based intervention affected employees' behaviors in respirator use and safe work practices that strived to avoid exposure to hazardous chemicals.

2.0 LITERATURE REVIEW

2.1 Occupational Exposure to Hydrocarbon Solvents

Extensive research has been conducted describing hydrocarbon solvent exposure. In 2000, approximately 350 articles containing quantitative hydrocarbon solvent exposure data were identified in the published literature. This included 16,880 hydrocarbon solvent exposure measurements from 99 selected articles. A review of this literature demonstrated that exposures to hydrocarbon solvents decreased fourfold from 1960 to 1998. Measurements reported that, on average, exposures were below 40% of the TLV since 1980.[7] Although this extensive literature was available describing an association between solvent exposure and symptoms such as a result of neurotoxicity, the etiology of repeated exposure to chronic, low level and acute, high level exposures was still debated.[8]

2.1.1 Exposure to Toluene and Other Solvents in Rotogravure Printing

The rotogravure imaging industry is a segment of the graphic arts industry that involves the high-volume printing of magazines, newspapers and more recently thermal imaging output media. Rotogravure printing involves an engraved cylinder rotating through an ink or dye pan. The ink on the cylinder is transferred by pressing the web (paper or mylar) against the cylinder with a rubber impression roller. The web then travels through an enclosed dryer that removes the volatile components of the ink. Dryer temperatures range from ambient to 120°F. Dryer exhaust passes to a pollution control device where solvent vapor is incinerated or recovered. Typical rotogravure ink is a low-viscosity material composed of pigment, binder and solvent.[9]

For large-scale rotogravure printing, solvent-based inks are the only ones used because of the need for an ink or dye carrier that has low viscosity and is easily vaporized. Water-based inks have proven to be of little value in rotogravure printing. The main sources of fugitive solvent vapors from rotogravure are solvent evaporation at the dye pans, the exposed section of the gravure cylinder, the web path from the impression nip to the dryer inlet, the dryer and the web after it exits the dryer.[10]

Toluene is used extensively as a solvent for the inks or dyes. It is usually mixed with other hydrocarbon solvents such as methyl ethyl ketone (MEK), methanol or cyclopentanone. Exposure information for specific solvent mixtures used in rotogravure printing is limited. A study of male workers exposed to solvent mixtures in printing, ink production and surface treatment plants was the most similar analysis found in the literature to the rotogravure printing press operation described in this paper. In that study, full shift exposures were monitored on Thursdays and Fridays with personal diffusive samplers in addition to end of shift biological monitoring of toluene exposure via urinary hippuric acid determination. The study population of 330 male workers was exposed to mixtures of 18 ppm toluene, 16 ppm methyl ethyl ketone, 7 ppm isopropyl alcohol and 9 ppm ethyl acetate. Exposure concentrations were reported as geometric means. A group of 135 male office workers served as the control. Although the mean toluene exposure was 18 ppm, some workers were exposed to concentrations up to 479 ppm. A summation of solvent concentration using the ACGIH additivity formula was calculated to be 0.31 (SD = 2.05). A ratio less than 1 indicated that the exposure to a particular mixture was acceptable, given that two or more hazardous substances have a similar toxicological effect on the same target organ or system. Hematology and liver function clinical chemistry measurements were also determined and study subjects completed survey questionnaires about symptoms experienced during work, when not at work and over a period of 3 months.

The entire exposed population was divided into subgroups based on exposure summation indices for the purpose of analyzing dose-response trends in symptom reporting. In addition, among the study population, 207 workers were exposed to MEK, toluene and other solvents; 108 exposed to IPA as well as to toluene and other solvents. In order to investigate the effects of these mixed exposures, 74 MEK or IPA exposed subjects were matched to workers with similar toluene exposure minus MEK or IPA. Hematology and liver function measurements were similar between treated and control groups. Significant ($p<0.1$) dose related increases in the prevalence of subjective symptoms during work relating to mucous membrane irritation (eye and nasal irritation) and central nervous system effects (floating sensation, drunken feeling) were noted. The prevalence of the additional symptoms experienced after work were also significantly increased; these included dizziness, "muddleheadedness", general dullness, rough skin, body weight loss and reduced sense of smell. A dose-related difference was noted in dizziness and rough skin. There were not significant ($p<0.05$) differences in symptoms between toluene, toluene and MEK or IPA groups. Urinary hippuric acid excretion was not changed by co-exposure to IPA or MEK. Multivariate analysis showed that toluene was the most powerful determinant of eye irritation symptoms; MEK did not contribute to irritation under the conditions of the study.[11]

Subtle neurological effects as reflected in psychometric performance measures have been reported in humans following acute exposure to toluene concentration of 75 – 150 ppm.[12] This exposure range includes the reported threshold for irritation, which is 100 ppm. These were the critical effects for toluene noted in this study. The toxicity of toluene paired with other solvents is summarized in table 1.

Table 1. Toxicity of Solvent Pairings.

Chemicals	**Exposure/Dose**	**Interactive Effect**	**Reference**
Toluene and MEK in humans	Toluene at 50 ppm and MEK at 100 ppm by inhalation for 4 hrs.	No additivity in tests of alertness and psychomotor function	Dick, *et al.*, 1984[13]
Toluene and ethanol in humans	Workplace inhalation exposure to toluene and history of regular ethanol consumption	Decreased blood toluene concentrations compared to those who did not drink regularly.	Waldron *et al.*, 1983[14]
Toluene and ethanol in baboons	10,000 ppm ethanol and 750 ppm toluene by inhalation for 2-3 hrs.	Decreased response rate and increased response time as compared to either solvent alone.	Hartmann *et al.*, 1984[15]
Toluene and ethanol in rats	Toluene: 1750 ppm , 6 hr/day, 5 days/week for 4 weeks (whole body) Ethanol: 4 g/kg/day	Changes in auditory-evoked brainstem potentials and outer hair cell loss in the ear as compared to toluene alone. Significant decrease in hippuric acid urinary excretion rates compared to toluene alone: inhibits metabolism.	Campo *et al.*, 1998[16]

Toluene and ethanol in rats	2-5% ethanol in liquid diet and 500 ppm toluene by inhalation for 4 hrs. (whole body)	Increase in *in vivo* toluene metabolism as compared to toluene or ethanol alone.	Sato *et al.*, 1980[17]
Toluene and ethyl acetate or 1-butanol in rats		No more than additive result on neurotropic effects and blood and brain solvent concentrations	Frantaik and Vodickovaa, 1995[18]
Toluene and methanol in rats	Methanol/toluene 300/30, 300/300, 3000/30 or 3000/300 ppm 6 hrs./day, 5 day/week for 4 weeks.	Nasal passage inflammation at higher incidences in rats exposed to mixture than either solvent alone.	Poon *et al.*, 1994[19]

These studies were in agreement showing that metabolism was not modulated by the presence of toluene with other solvents at low exposure levels. The basis for occupational exposure limits to mixtures of these solvents was indicated to be avoidance of mucous membrane irritation. Mucous membrane irritation caused by mixture was generally regarded as an additive effect. One study found a synergistic effect on nasal irritation in rats exposed simultaneously to methanol and toluene at levels considerably higher than time-weighted average exposures occurring at the company represented in this current research.[19] It was not known if this synergy was possible in humans at the time-weighted average concentrations measured at the company represented in this study.

2.2 Hydrocarbon Solvent Exposure Control

Control of hydrocarbon solvent exposure begins at the design stage of a process. Safety and health hazards must be anticipated and recognized at this stage in order to implement the most cost-effective and preventive control strategy. In the rotogravure printing industry, control of hazards associated with hydrocarbon solvents is essential. Presently, water-based solvents are not feasible or effective. Process engineers with the assistance of occupational hygienists developed the control strategies for the hydrocarbon solvents selected. At the rotogravure printing press involved in this study, combinations of engineering and administrative controls were used to reduce occupational exposures to the solvents. Engineering controls consisted of negative air pressure cylinder and dye stations that prevented solvent vapors from escaping the coating machine and product and process design that limited the number of times an operator needed to interface at the machine enclosure. Administration controls included work practices that limited the frequency the operator entered the machine enclosure. Operation of these types of printing presses required employees to interface with vital machine components inside the machine enclosure. Engineering and many administrative controls to prevent this operator interface were not feasible. Due to the vapor concentrations inside the machine enclosures, supplied air respirators must be worn to protect against the effects of hydrocarbon vapors.

2.2.1 Use of Respirators

The Bureau of Labor Statistics conducted a national respirator survey indicating that several thousands of establishments may not be in compliance with OSHA regulations in 29 CFR 1910.134. The questionnaire consisted of thirty-two questions. Questions were asked about the type of respirator worn at the establishment, respirator program management and respirator use practices. Of 276,000 establishments surveyed, 47.2% answered "No" when asked if an assessment of employees' medical fitness to wear respirators was conducted. 4.9% did not know if a medical assessment was conducted for employees who wear respirators. Other areas of deficiency in respiratory protection programs included the requirement to fit test for the required use of tight-fitting respirators.[4] To ensure quality control in the selection, maintenance and use of respirators, it is universally accepted that the effectiveness of such protection depends upon the institution of a respirator program. To evaluate the quality of respirator programs in typical workplaces, a previous study analyzed the history of compliance with OSHA standards. This study concluded that in most cases (55.6%) where respirators were used as a hazard control, the respiratory protection programs were deficient in at least one element. This may have increased the potential for employee exposure to hazardous atmospheres. It was also concluded that 27% of inspections in which respirator programs were reviewed resulted in a citation of a specific element of the respiratory protection program.[20]

A respiratory protection program that meets the OSHA regulatory standards did not necessarily translate into 100% compliance with respirator use requirements. Several studies have assessed factors that affect workers' use of respiratory protection equipment. The findings of a two-part study provided insight into the broad range of factors that influenced workers' perception of and experiences with their respirators. The first phase of the study was designed to understand attitudes and beliefs about respirator use among hazardous waste workers. Interviews were conducted for 28 respirator users. Subjects were asked to describe their knowledge, attitudes and beliefs about their risks to hazards at their worksites and to discuss their use of respirators. Issues and concerns generated from these interviews fell into three categories; 1) Knowledge, Beliefs and Attitudes, 2) Physical and Psychological Effects and 3) External Influences. These categories were broken down further to understand specific factors affecting use of respiratory protection equipment.[21] The second phase of the study utilized the factors identified in the first phase to develop a questionnaire administered to eligible respondents. 255 respondents scored the 18 factors identified in phase 1 of the study. Scores were compared to type of respirator, frequency of use and associated health symptoms. It is important to note that nearly 20% of the respondents in that study wore air-supplied respirators. In all categories, six factors were identified that negatively influenced respirator use. Five of those six fell in the category of Physical and Psychological Effects. The ability to "hear and be heard" and comfort issues were identified as the most negative aspects of respirator use. This two-part study concluded that when respiratory hazards were not eliminated, it was critical that organizations had effective education and respiratory protection training strategies in place. Successful programs will have many layers and many individuals involved such as health and safety professionals, managers and supervisors, co-workers and most importantly, the workers themselves.[5]

Other studies focusing on factors affecting respirator use pinpointed some obvious reasons workers chose to not wear a respirator. First was that respirators were not comfortable.[22] Second, many individuals learned that they could work in certain environments without wearing a breathing apparatus and they did not experience immediate effects. There was apparently a decision made by an individual not to tolerate the discomfort and nuisance associated with the wearing of respirators. It seemed appropriate to review the factors thought to be responsible for the development of discomfort while wearing a respirator prior to developing other strategies. One of the factors thought responsible for discomfort during respirator use was the psychological response referred to as a feeling of claustrophobia. However, very few investigations have been directly concerned with evaluation of this psychological response.[23]

Other studies investigating factors affecting respirator use included loss of visual field, productivity during a mentally stressing task, thermal discomfort of protective devices and cognitive performance during use of a respirator.[24-27] As part of a health survey of union painters, 169 male spray painters were questioned about their personal beliefs and social influences as determinants of respirator use. This study focused on several determinants of past and intended respirator use among spray painters. Results of a survey showed that painters who wore a respirator all of the time and those who intended to do so in the next year were slightly younger than the painters in the other corresponding use groups. Painters who intended never to wear a respirator were significantly older than those who always intended to wear a respirator. The frequency of past and intended use of respirators was lowest among the heavier smokers. Correlations existed between agreement that the respirator would be uncomfortable and that it would make breathing difficult. Conversely, a negative correlation existed between agreement that the respirator would be uncomfortable and that the painter would be at lower risk of cancer. Negative correlations were measured between intended respirator use and beliefs that the respirator would be uncomfortable, would get in the way, would cause difficulty breathing and would make the painter feel closed-in. Social influences were responsible for the largest negative correlation with intended use and the belief that others would think that the painter was foolish for wearing a respirator. Among those studied, the most important personal beliefs were in agreement with previous studies, that is, discomfort and inconvenience. The personal beliefs of health benefits were also related to the increased intention to use a respirator. However, this study showed it appeared to be less important that discomfort. Among spray painters, intentions to use a respirator were only partially predictive of behavior.[6]

2.3 Efforts to Increase Use of Respirators

2.3.1 Respirator Design Changes

Efforts to increase use of respirators have taken a variety of forms with mixed success. Referenced studies have shown that discomfort was one of the major factors affecting a respirator user. It may also have been the main reason workers simply chose to not wear a respirator. Respirator manufacturers used comfort as the principal reason to purchase one respirator over another. For this reason, respirator manufacturers extensively invested in studies of comfort. One study looked at the effect of evaporative cooling of respiratory protective devices on skin temperature, thermal sensation and comfort. A major source of discomfort while wearing respirators was high skin temperature. The results showed that under resting condition the skin temperature against an uncomfortable mask decreased making the mask significantly more comfortable from skin temperature aspects thereby making the mask more acceptable to the user.[28]

2.3.2 Respiratory Protection Program

For tasks that required the use of supplied air respirators, comfort was less of a factor for users than for those tasks that required the use of only air-purifying respirators.[5] In such cases, pertinent literature concluded that compliance with OSHA standards for respiratory protection was essential to prevent exposure to inhalation hazards. Four elements for an effective occupational safety and health program included:

1) Establish clear rules. State clearly a worksite policy on safe and healthful work and working conditions;
2) Effectively communicate the rules and safety expectations, including goals and measures;
3) Verify that expectations are being met and hold managers and supervisors accountable for enforcing the rules consistently;
4) Implement a disciplinary program to reinforce the positive and the negative behaviors.

An effective respiratory protection program should meet the above stated elements for any effective safety and health program. A respiratory protection program should include:

1) Written standard operating procedures
2) Responsibility for program assigned to a single individual
3) Annual review of employee suitability based on physicians guidelines
4) Use of approved respirators
5) Selection procedure for respirator type

6) Training of employees

7) Fit testing of employees

8) Policy of facial hair, contact lenses, eye and face protection

9) Procedure for issuing respirators

10) Procedures for pre-use inspection of respirator

11) Procedure for mentoring respirator use

12) Environmental monitoring of airborne concentration

13) Medical surveillance and biological assay, where applicable

14) Procedure for cleaning, maintenance and repair of respirator

15) Annual program evaluation[29]

Of cited overexposures to substances listed under 29 CFR 1910.1000, 72.1% resulted in a subsequent citation for specific program deficiencies.[4] However, as indicated previously in this paper, a respiratory protection program that meets the OSHA regulatory standards did not necessarily translate into 100% use of respirators.

2.3.3 Exposure Characterization

Selecting respiratory protection equipment without an understanding of the workplace and potential exposures may result in workers not using the selected protective equipment at all. Characterizing workplace exposures aid the identification and control of those exposures. Innovative techniques have been implemented which focused recommendations at controlling inhalation hazards. One technique was the use of direct reading instruments and data recording devices to monitor and store data characterizing worker exposures in order to help identify the sources of worker exposures. Researchers with the National Institute for

Occupational Safety and Health (NIOSH) developed a systematic approach to help identify the sources of worker exposures and to provide an effective means for communicating the results to workers and management. The system employed:

- Direct reading instruments and data recording devices to monitor and store data characterizing worker exposures,
- Video camera and recorder to document work activities,
- Task analyses to evaluate work activities,
- Statistical techniques to develop predictive models and to summarize the results, and
- Personal computers to perform analyses on the data and to combine the activity data and the exposure data into a presentable form.

The use of real-time data acquisition was useful for complex processes or work cycles where exposure patterns were difficult to evaluate using traditional integrated workplace samplers such as pumps with filters and charcoal tubes. The three data acquisition studies evaluated by NIOSH of complex processes included manual weigh-out and transfer of powders, dust control during automotive brake servicing and emission characterization of an evaporative pattern-casting process. Each of these studies proved that videotaping utilizing real-time instrumentation served well to identify activities in a work cycle that changed worker exposure. This was accomplished by allowing a repeated detailed review of the work cycle or process while tracking worker exposures. Limitations of this study noted by the authors were system improvements including increased portability of equipment and better data resolution.[30,31]

As visualization methods improved through advances in real-time monitoring instruments, video technology and computer use, methods for workers to see with their own eyes and in real time the levels of potential hazard to which they are being exposed was becoming a realistic possibility. One methodology named PIMEX was created. Case studies were made in nine workshops in Scandinavia. One company identified exposure dose to welding fumes as unacceptable. What was discovered with the visualization technique was the local exhaust system needed to be used more effectively to reduce exposures. In such workplaces, where the worker controls the contaminant source, it was often possible to reduce exposure dose by 90% almost immediately simply by using the existing equipment more effectively.[32] Although visualization techniques have proven effectiveness in identifying and controlling workplace exposures, continuing research and development needs to occur to improve these tools. Until multidisciplinary research groups conduct this research, occupational safety researchers write that we will continue to increase the stack of knowledge about risks and control methods, but without getting that knowledge to the workers who can use it.[33]

2.3.4 Interventions

The goal of occupational safety and health interventions is to prevent disease and injury through the combination of techniques such as control technologies, exposure guidelines and regulation, worker participation programs and training. The goal of intervention research is to determine the efficacy and effectiveness of these techniques and programs. The National Occupational Research Agenda (NORA) identified research opportunities for evaluating the impact of interventions on safety and health outcomes. The ultimate questions asked were what works best at enhancing worker safety and health and why it does or does not work. Introduction of effective safety and health programs continued to be driven by demands that they documented cost-effectiveness and impacts on health. NORA identified that corporate safety and health programs, regulatory requirements and voluntary consensus standards, workers' compensation policies and loss-control program engineering controls, and educational campaigns were among the types of interventions that needed to be developed, implemented and evaluated. Data collected from such research will direct effective strategies to improve the safety and health of workers.[34] Occupational safety and health effectiveness research told us the extent to which an intervention worked or did not work under "real-world" conditions. Effectiveness studies answered such questions as:

1. To what extent did the intervention reduce occupational injuries, illnesses disability or fatalities?
2. To what extent did the intervention reduce worker exposure to hazardous conditions?
3. What was the effect of the intervention on the social and economic consequences of work injury and illness?
4. How did workers' knowledge, attitude or behaviors change because of the intervention?[35]

Occupational safety and health interventions traditionally have included training as an important component. A literature review of training intervention efforts was conducted which focused on designs to enhance worker knowledge of workplace hazards, to affect behavior changes that may ensure compliance with safe work practices or to prompt other action aimed at reducing the risk of occupational injury or disease.[36] Eighty such studies were reviewed and included in the literature review paper. Several of those address training effectiveness aimed at controlling health hazards associated with chemical agents.

With the aid of the above cited literature review, NIOSH developed a model for research on training effectiveness with the intent to offer a general approach to intervention effectiveness research that addressed formal training across setting and topics. The NIOSH model, known as Training Intervention Effectiveness Research (TIER) integrated primary and secondary data collection with qualitative and quantitative analyses in order that the benefits of each research technique be applied to the assessment of training effectiveness.

Intervention research, in many cases, will attempt to evaluate alternative and innovative techniques' effectiveness at reducing worker exposure to hazardous conditions. One study looked at the use of hearing protectors and a possible intervention strategy to increase the users' acceptance of hearing protectors. Baseline observations of earplug use were collected in both the experimental and control departments for a period of one month. Walk-through tours of all workstations in both departments were made along a fixed route and repeated at random times. After baseline observations were made, lectures were given to groups of workers in the experimental and control groups on the aspects of hearing conservation in noise. Pre-shift and post-exposure hearing testing then began for the experimental group on the day after the lectures and continued for one month. Workers in the experimental group were then given feedback that consisted of graphs showing pre-shift audiometric exam results and post-exposure audiometric exam results. Five months of follow-up observation began to examine the aftereffects of the feedback on the use of earplugs in the experimental group. The researchers clearly observed that the feedback procedure employed in this study had a positive and sustained effect in changing worker behavior with regard to the increase use of hearing protection.[37]

In a study identifying determinants of respirator use among construction painters, it was concluded that intentions were only partially predictive of behavior. The researchers administered a questionnaire at the time of the workers' health examination. Painters were asked how frequently they wore chemical cartridge respirators over the entire time they had worked and how frequently they intended to wear a chemical cartridge respirator while spray painting over the next year. Additional questions were asked concerning the painters' beliefs and attitudes toward respirator use. A correlation matrix was constructed. The correlation between agreement that the respirator would be uncomfortable and that it would make breathing difficult was 0.60. However, the correlation between agreement that the respirator would be uncomfortable and that the painter would be at lower risk of cancer was –0.04. More results showing negative and statistically stable ($P<0.001$) correlations were measured between intended respirator use and beliefs that the respirator would be uncomfortable (rho = –0.45), would get in the way (rho = –0.40), would cause difficulty breathing (rho = –0.43) and would make the painter feel close-in (rho = –0.45). Further correlations were noted and concluded that beliefs about potential health benefits were related to increased intention to wear a respirator, but they also appeared to be less important than beliefs about discomfort. The authors of this study concluded that respirator use is a social behavior and that perceived attitudes of others in the workplace influenced respirator use. It was concluded that inclusion of supervisors and managers may prove to be useful as part of a training intervention program. It was also concluded that the intervention strategy for increasing use of respirators should be multidimensional focusing on several different determinants of respirator use. Training alone may have had limited success.[6] What message needed to be delivered and who delivered the message were vital to the success of any training intervention. If health campaigns were to influence an audience as intended, appropriate messages should have been developed that motivate someone to act. One framework that has been developed was the Persuasive Health Message framework. It was agreed that a persuasive health message should contain a threat message and an efficacy message. A threat message tried to make the intended audience feel vulnerable to a severe threat while the efficacy portion of the message may have convinced employees that they can prevent the threat by performing a recommended response. Both threat and efficacy messages must be high.[38] For example, the persuasive health message that could be communicated to operators of a rotogravure printing press was the threat of adverse health effects due to organic solvent exposure. The efficacy portion would be adherence to company expectations of respirator use or utilizing safe work practices.

Various cues may have influenced how a health message was accepted. The source of the message was one cue that had an indirect affect of the acceptance of the message. For example, was the person delivering the message credible or did the person delivering the message have leadership influence over the recipients? Use of leaders (e.g., supervisors, managers, etc.) in the health message communication has been determined to be an important cue to the message recipients that the message is important and the threat and efficacy should be considered. As such, a model presented by Dov Zohar[39] focused on the inclusion of supervisors and managers as suggested by other intervention effectiveness research. Effective line supervisors provided the antecedents (training and goal setting) and consequences (feedback and incentive). Two primary attributes of effective supervision were performance-based monitoring and timely communication of consequences. The practice of performance-based monitoring clarified a supervisor's directives and expectations.[40] Supervisors who had these attributes demonstrated the understanding of their responsibility for the safety of their subordinates. Zohar presented this leadership-based model with the distinctive feature of modifying supervisor safety practices to introduce change. Three hypotheses were tested in the study: 1) Improved supervisory safety practices will result in better subunit safety records; 2) Improved supervisory safety practices will result in higher safety climate in organizational subunits; 3) Improved supervisory safety practices will result in higher rates of earplug use in organization subunits. This leadership-based intervention phase lasted 8 weeks. Supervisors were given weekly feedback from researchers as to reported episodes between supervisors and their subordinates in which safety was the criterion for supervisory approval or disapproval. The information was obtained by researchers during brief interviews where the worker described safety-related interactions they had with their supervisor. Workers were assured anonymity. While the first two hypotheses were important in showing the effectiveness of this leadership-based intervention model, the third hypothesis test (testing rates of earplug use) was key in the development of the current research question posed in this dissertation. The recording of earplug use after the intervention occurred began only in the third week of the intervention, resulting in missing baseline data. However, study results did show an increase in earplug use as a result of the intervention. This study concluded that a leadership-based model for interventions offers several advantages. The interaction between supervisors and subordinates was an ongoing relationship that should be used instead of relying of outside eyes to communicate antecedents and consequences. It resulted in the role change where safety becomes the responsibility of the supervisor and not safety personnel. This also provided an innovative approach to safety leadership that may be well accepted by higher-level management.

3.0 RATIONALE, HYPOTHESIS AND SCOPE

3.1 RATIONALE

Many workers may not change their safety behaviors based simply on a requirement handed down from management or the site safety professional. Additionally, a recent survey conducted by the Bureau of Labor Statistics indicated that many companies might be in violation of respirator use requirements.[4] It was also concluded that efforts to change only a worker's beliefs may have had limited success and that the most effective intervention strategy would be multidimensional.[5] Research needed to be conducted to determine if new intervention techniques changed safety behaviors and improved respirator use and associated safe work practices. The techniques presented in this research may be applied not only to respirator use but also to other types of personal protective equipment use.

3.2 HYPOTHESIS

The use of employee-conducted air monitoring and video monitoring of certain tasks requiring the use of a respirator will provide workers with information about the exposure risk to organic vapors in their area. This information described the importance of wearing respirators and adhering to safe work practices. The information provided above combined with a leadership-based intervention will increase employees' use of respirators and adherence to safe work practices when required.

The objectives of the study were as follows:

1. Determine if employees' intentions of respirator use are predictive of behavior.
2. Determine if the leadership-based intervention coupled with employee-conducted air monitoring will increase respirator use and adherence to safe work practices aimed at preventing exposures.
3. Describe the ability of a leadership-based intervention to affect employees' attitudes.

3.3 SCOPE

This research was limited to assessing a leadership-based intervention model combined with employee-conducted air monitoring for workers who had elevated exposure doses to organic solvents while performing tasks on a rotogravure coating machine. This machine consisted of eight coating stations where the potential for exposure to organic solvents existed for the operators, technical staff, and mechanics. Company expectations were that respiratory protection be used for any task that required the machine operator to break the plane of the enclosure (i.e., enter the machine during coating operation). Adherence to the company expectations of respirator use was estimated to be poor (0 to 50% respirators use). Upon reviewing baseline video monitoring data, respirator use while inside the machine enclosure was 0%.

The organic solvent monitored by employees was toluene. The direct-reading instrument used was MSA short-term detector tubes specific to toluene using an MSA Kwik-pump®.

Video monitoring was confined to one coating station on the machine. Video monitoring was used to monitor frequency and duration of exposure (i.e., how often the operator entered the machine enclosure and the time spent inside the machine enclosure during a work shift). This information was used for training purposes. Binary use of respirators or safe work practices (i.e., yes, the worker used the respirator or safe work practices; or no, the worker did not use the respirator or safe work practices) was also used. This qualitative data was used in the data analysis of the project.

Company expectations were that safe work practices be followed whenever an operator on the coating machine interfaced with the machine inside the coating enclosure. The safe work practices included use of tools such as cleaning sticks and machine stops that eliminated the solvent vapors in the enclosure. If it was not feasible to use safe work practices, respirator use was required to enter the enclosure.

Leaders used in the intervention were direct supervisors, the operations manager and focus persons (area team leader assigned to work with one of four crews).

The purpose of this research was to examine possible associations between certain determinants and intended use of respirators or adherence to safe work practices focused on avoiding overexposures to coating solvents. The intention was not to estimate prevalence of intentions, attitudes or effects of respirator use. The intention was also to compare respirator use as a company expectation and not as OSHA compliance.

4.0 METHODS AND MATERIALS

4.1 Overview

The purpose of the present study was to determine the effect of a multifaceted leadership-based intervention on employees' use of respirators and safe work practices to avoid exposure to organic solvents. The leadership-based intervention model used in this study was designed from Zohar's model with techniques for observation and frequency for the intervention from the Hopkins' study.[41]

The overall sequence of events was:

1. Pre-intervention video monitoring.
2. Distribute pre-intervention questionnaire (See Appendix A)
3. Intervention
    a. Leader met with individual workers in an office/interview environment for 5-10 minutes to discuss the use of a respirator and safe work practices as a means to protect their health.
    b. After the initial training, the leadership team visited the work area for 3-5 minutes daily to specifically praise workers for using the PPE and/or safe work practices and give any suggestions if workers failed to wear the respirator for a task that required its use.

c. Employee-conducted air sampling. Each worker had the opportunity to conduct real-time samples for the solvents present.
d. Educated workers about the health effects associated with short-term exposure to high levels of toluene.
e. Trained in the proper use of airline respirators (per OSHA requirements).

4. Post-Intervention Questionnaire (See Appendix B)
5. Phase 2 video monitoring
6. Data analysis

4.2 Subject Selection

Forty-one individuals were identified as potential subjects for this study, forty males and one female. Twenty-nine subjects were strictly coating machine operators, nine subjects were strictly chemical mixing operators, and three subjects were both chemical mixing operators and coating machine operators. Subject ages ranged from 22 to 59 years during the data collection period of the study. All 41 subjects were asked to complete a written consent form agreeing to all study requirements, which included a statement indicating that subjects were allowed to withdraw from the study at any time. It was explained that the Colorado State University Human Subjects Review Committee had approved this study protocol. A pre-intervention questionnaire was provided at that time. Subjects provided information on age, tenure with company and tenure at current position in the company.

Of the 41 individuals who participated in the pre-intervention questionnaire, only 14 were recorded on both pre- and post-intervention video monitoring. The researcher expected to see 32 total individuals on both the pre-intervention monitoring and the post-intervention monitoring based on previous observations. This estimate comes from 29 operators who work solely on the coating machine plus three workers who work in the chemical mixing area and on the coating machine. However, the researcher did not begin viewing the videos until after the study was completed. Changes to work practices limited the number of operators who conducted tasks inside the machine enclosures. The researcher had no control over how often an operator would be viewed on the video. The video monitoring would have needed to be extended to an unreasonable amount of time to capture all 32 coating machine operators on the video. Therefore, only the questionnaire data and video data for these 14 individuals were used for all aspects of this study.

The nine operators identified as chemical mixing operators did wear respirators but for tasks completely separate of any task that tasks place on the machine. These individuals participated in the pre- and post-intervention questionnaires. At no time were these operators observed in the video monitoring. The study was not designed to have a control group for comparison of either the questionnaires or the video monitoring. Due to this, the researcher believes it would not be worthwhile to compare the questionnaire data of operators not viewed on the video observations to those of the operators who did have data sets in both the pre- and post-intervention video monitoring.

4.3 Pre-Intervention Video Monitoring

A video camera (Panasonic CCTV, Model WV-BP134, Serial No. 87W09561) was installed at one of the eight stations of the coating machine. Images were recorded using a Sony time-lapse videocassette recorder, Model SVT-3050 at a recording speed set at the 120-hour mode. The video was used to capture the frequency and duration of tasks that required the workers to be inside the station where exposures to solvents occurred. The camera was installed six weeks prior to image capture. Phase 1 video image capture took place over a three-week period. Each crew was video taped for five days in that three-week period. Fulfillment of company safety expectations during a coating station interface episode was defined as the number of times the station enclosure was opened by that employee resulting in no exposure (due to work practice or respirator use). Two observers watched the video independently with specific definitions of what constituted fulfillment of company safety expectations at the coating machine station.

4.4 Pre-Intervention Questionnaire

Workers in the target population provided information about how frequently they wore air supplied respirator over the entire time they worked on coating machine and how frequently they intended to wear air-supplied respirators while inside the machine enclosure over the next year. On a scale of one to six, workers rated the degree to which they agree or disagree with the statement, "If I wore an air supplied respirator every time I entered the 291 Machine, then...," completed with a consequence listed in Appendix A.

The questionnaire was administered after initial video monitoring but prior to the intervention. All questionnaires were administered at the worksite.

4.5 Intervention

The overall goal of the intervention was to prevent adverse health effects related to solvent exposure doses. Two behaviors were targeted for improvements in the intervention. The first was increasing respirator use. Company expectations were that respirators were to be used when operators entered the machine enclosure during coating activities. Respirators prevent adverse health effects related to solvent exposures. The second behavior was adherence to safe work practices that focused on avoiding entrance into the machine. These practices included keeping one's head from breaking the plane of the enclosure by either body position, utilizing machine stops that eliminates vapor generation or using tools provided. Adherence to these practices also prevents exposure to solvents and the related adverse health effects.

The framing of the intervention was constructed as already fitting within the target population's current belief and behavioral system. The best campaigns (or interventions) were those that were framed to fit within acceptable beliefs, attitudes and behaviors.[38] Because workers in this area have demonstrated to have positive attitudes toward safety and health, focusing the intervention on specific safety and health behaviors was the appropriate strategy.

4.5.1 Leadership-Based Intervention

As mentioned previously, the leadership-based intervention model used in this study was designed from Zohar's model with techniques for observation and frequency for the intervention from Hopkins' study.[41] This included timely feedback given by direct supervisors as explained in the model. The leadership team for this study consisted of the line manager, two supervisors and four focus people.

Line Manager: The line manager conducted frequent walk-throughs of the area on a daily basis. These walkthroughs consisted of safety, quality and productivity checks. For the intervention, the line manager added respirator use and safe work practice observation to his daily walkthroughs. During the three week intervention period, the line manager gave proper recognition to operators for fulfillment of company safety expectations and coached in circumstances where improper use or non-use of respirators or safe work practices occurred.

First Line Supervisor: Coating machine operators were arranged in four crews working rotating 12-hour shifts, 7 days per week. A supervisor was assigned to two separate crews. First line supervisors were directly responsible for safety, quality and productivity performance of each operator under his or her supervision. First line supervisors met periodically with each operator to discuss performance. These performance reviews were conducted in a closed office environment. Supervisors also spent extensive amounts of time on the production floor monitoring safety, quality and productivity. For the initial part of the leadership intervention, the first line supervisor met with each employee in an office environment to discuss expectations of respirator use and adherence to safe work practices. This included when to wear the respirator and reasons to wear the respirator. The supervisor referred to the respirator use expectations stated in the department's respiratory protection procedures. These expectations stated that respirators were to be worn whenever the face of the operator breaks the plane of the machine enclosure when the machine is “at-coat”. Operators may open the enclosures and conduct work as long as their face does not break the plane. This was the safe work practice supervisors reinforced. The researcher instructed the supervisor about how the meeting with the individual operators was to be conducted. This instruction took place on a one-time basis.

The second part of the first line supervisor intervention included brief interviews with operators on the machine floor. These interviews occurred daily for three weeks. The interviews included: a) asking the operator for a 1-2 sentence description of any episode where the operator used a respirator or the safe work practices, b) giving positive recognition for proper use of the respirator and safe work practices, and c) coaching the operator if improper or non-use of the respirator or safe work practices was observed.

Focus Person: Each of the four crews consisted of a lead operator called a focus person. The focus person’s primary responsibility was coating machine production. The focus person had direct contact with each member of the crew during day and night shifts. The focus persons’ involvement in the intervention included recognition for proper use of respirators and safe work practices and coaching for improper or non-use of respirators or safe work practices.

4.5.2 Employee-Conducted Air Sampling

3M® organic vapor monitors (passive diffusive) and a Foxboro TVA 1000B with data logging capabilities have been used to determine current exposures to organic solvents in the stations. Results of those studies indicated that the regulatory short-term exposure limit (STEL) and ceiling limit for toluene were not exceeded when operators enter the machine enclosure. Instantaneous measurements inside the machine enclosure resulted in elevated concentrations of toluene. Thus, the company instituted internal procedures and expectations requiring employees to use respirators whenever the face of operator broke the plane of the machine enclosure. Safe work practices that protect operators from the elevated solvent concentrations such as using tools, body positions and machine stops were also part of the internal procedures For the purposes of this research, workers conducted air monitoring using MSA detector tubes specific to the organic solvents used in the process. Each worker took one sample inside the machine enclosure to demonstrate the concentration of contaminants in the operator's breathing zone. The researcher then interpreted the results for the worker in terms of exposure and dose. The results were used to demonstrate to the workers the elevated concentrations inside the station enclosure. The air sampling using detector tubes took place after the Phase 1 video monitoring, the pre-intervention questionnaire and the leadership-based intervention.

4.6 Post-Intervention Questionnaire

Once the intervention was completed, all participating subjects completed a post-intervention questionnaire at the worksite. The questions consisted of 19 questions based on a six-point scale. These questions come partially from a study on group-level model of safety climate.[42] The purpose was to explore supervisory action and expectation and to understand how well the subjects understood contaminant concentration levels inside the machine enclosure and expectations of respirator use.

4.7 Post-Intervention Video Monitoring

This step involved the video monitoring of workers at the machine after the intervention had taken place. Video monitoring took place over a three-week period starting one month after the intervention was complete. Video monitoring analysis included only workers who were involved with all phases of the study.

4.7 Data Analysis

The goal of the data analysis was to answer the question: How much change occurred as a result of the intervention[43] and, were intentions to wear respirators predictive of behavior?

Descriptive statistics (mean, range, standard deviation) were calculated on all measurements and observations including the six-point scale of the questionnaire. An ANOVA for repeated measure was the recommended statistical test for determining the variability within and between measurements in the study (independent variable = time).[44] However, the repeated measure ANOVA was not possible due to the lack of consistent data (i.e., data showed too many missing values). Correlation tests were also evaluated for each part of the questionnaires and subsequent video observations. The measurement in the study was the comparison of frequency and duration of tasks inside the machine enclosure pre- and post-intervention. A data tracking system was developed for these measurements. For agreement and reliability purposes, two separate observers tracked the video monitoring data. The observers were the researcher and another CSU graduate student. Inter-rater agreement and reliability for the two raters were compared for episodes, time and non-use of respirators or work practices. Included in the conclusions was a comparison of any productivity changes due to the hypothesis stated previously in this protocol.

5.0 RESULTS AND DISCUSSION

The hypothesis of this study was that multifaceted intervention efforts including leadership-based intervention and employee conducted air sampling will increase respirator use and safe work practices that prevent employee exposures to organic solvents. In order to measure the effects of such an intervention, three study objectives were determined. Discussion of these objective follows in three sections: Section 5.1 focuses on the pre-intervention questionnaire and if intentions predict behavior; Section 5.2 presents statistical and observational analyses of pre-intervention and post-intervention video monitoring, and Section 5.3 involves a review and analysis of the post-intervention questionnaire to describe the ability that a leadership-based intervention affected employees' attitudes.

5.1 Pre-Intervention Questionnaire Intentions and Behavior

The results for intentions predicting behavior are covered in two sections. The first deals with the correlation between intentions of respirator use and the proportion of respirator use after the intervention. The second section reviews results of a multiple regression analysis to understand if prior attitudes and intentions predict post-intervention respirator use. The technique used was a questionnaire presented to the recruited coating machine operators. The questionnaire contained two questions focused on obtaining the past respirator use and future intentions of respirator use for each operator. Fourteen questions follow which were intended to predict post-intervention respirator use based on attitudes prior to the intervention. The reliability of the data collected for behavior and attitudes toward respirator use during this study was conducted using Cronbach's alpha, a measure of internal consistency. Coefficient alpha for all cases of the 14 items together was calculated to be .822. The value demonstrates acceptable reliability.

5.1.1 Descriptive Statistics of Subjects

Descriptive statistics for the subjects participating in the study are presented in table 2.

Table 2. Descriptive Statistics of Participants.

		Age in years	Gender	Company tenure	Position tenure
Number of Subjects	Valid	12	12	12	12
	Missing	2	2	2	2
Mean (years)		37.75	0.00	11.75	2.73
Std. Deviation		8.614	0.00	8.696	2.191

Of the 14 subjects who participated, 2 subjects did not complete a pre-intervention questionnaire asking for age, company tenure or tenure at current position. The study results for these two subjects were not used in the analysis presented.

5.1.2 Intentions Predicting Behavior

Table 3 describes the frequency of past and intended respirator use among the 14 subjects. No subject intended to never wear a respirator in the future. 25% of the subjects intended to wear a respirator all the time when working inside the machine enclosure. Table 4 compares the characteristics of subjects based on past and intended use of respirators. The twelve respondents to the questionnaire were separated into three use groups. For past use, those who answered they used a respirator never or sometimes were grouped as low past users. Those who indicated they wore a respirator about half the time, most the time or all the time were grouped as high use. For intended use, those who answered they intended to never use or sometime use a respirator were grouped as low intent users. Those who answered they intended to wear a respirator about half the time, most the time or all the time were grouped as high intent users. The average age for the three groups is 38.8 years. The average time with the company is 12.7 years. The average position tenure for each group is 2.2 years.

Table 3. Frequency of past and intended respirator use.

Frequency of Use	Past Use (%)	Intended Use (%)
Never	16.7	0.0
Sometimes	41.7	33.0
About half the time	16.7	8.3
Most the time	25.0	33.0
All the time	0.0	25.0

Table 4. Characteristics of operators grouped by past and intended respirator use.

Use group	Number	Age (years)		Company tenure (years)		Position tenure (years)	
		Mean	SD	Mean	SD	Mean	SD
Low past/high intent	3	39.6	10.9	12.9	10.0	2.2	2.4
Low past/low intent	4	38.7	10.1	12.5	9.0	2.2	2.3
High past/high intent	5	38.2	8.3	12.8	8.5	2.3	2.3

A Pearson Correlation test was used for results obtained from the pre-intervention questionnaire and the post-intervention video monitoring. Refer to table 5 for these results. The correlation between future intentions for respirator use when inside the machine enclosure and average post-intervention proportion of non-use of respirators is negative (-0.161). This indicates that as intentions get stronger, the subjects used respirators to protect them from solvent vapors. However, this correlation of predicting behaviors from intentions failed to yield a statistically significant result at $p<.05$ and thus the hypothesis cannot be accepted.

The correlation between tenure with the company and the pre-intervention proportion of non-use of respirators is statistically significant ($r=.591$, $p=.043$). Results indicate that the longer you are with the company, the more likely you are to not meet company expectations for respirator use. The correlation between tenure as a machine operator and post-intervention non-use of respirators is also statistically significant ($r = .613$, $p = .034$). This suggests that the longer you have been working as an operator on the coating machine, the more likely you are to not meet company expectations for respirator use even after an intervention has been presented. For the pre-intervention questionnaire, answers for the past use of respirators correlated with answers for intended use of respirators are statistically significant ($r = .606$, $p = .037$). This proposes that if, for example, an operator used a respirator 40 to 60% of the time in the past when required by the respirator use procedures, they are likely to wear a respirator 40 to 60% or greater of the time in the future when required. Finally, the correlation between the average pre-intervention proportion of non-use of respirators and the average post-intervention proportion of non-use of respirators is significantly correlated (r = .602, p = .023). This indicates that individuals who do not use respirators according to company expectations prior to the leadership-based intervention will continue to not use a respirator after the intervention has taken place.

Table 5. Pearson Correlations Among Study Variables (N = 12)

Variable	1	2	3	4	5	6	7	8	9	10
1. Age	--									
2. Gender	*	--								
3. Company tenure	.412	*	--							
4. Position tenure	.243	*	.437	--						
5. Past Use of Respirator	-.238	*	-.226	-.463	--					
6. Intentions for Respirator Use	.087	*	-.161	.076	.606#	--				
7. Pre-intervention attitudes	.056	*	.228	.123	-.363	-.234	(.822)			
8. Post-intervention attitudes	-.057	*	.371	.351	.035	-.091	-.326	(.820)		
9. Pre-intervention non-use of respirators	.334	*	.591#	.333	.016	-.002	-.036	.186	--	
10. Post-intervention non-use of respirators	.166	*	.185	.613#	-.238	-.161	-.297	.166	.602#	--

Note. # - p < .05
* - Cannot be computed because at least one of the variables is constant.

5.1.3 Attitudes Predicting Non-Use of Respirators

Multiple regression analysis was used to see if prior attitudes (pre-intervention questionnaire) and intentions predict post-intervention respirator use. These results are presented in table 6. R-squared is interpreted as the percent of variance accounted for in the dependent variable by the independent variable. The R-squared value of .144 and the Adjusted R-squared value of -.046 (F=.790, p=.483) indicates that the two independent variables (attitudes and intentions) do not significantly predict respirator use.

Table 6. Multiple Regression for Predicting Respirator Use from Prior Attitudes

R	R-Square	Adjusted R-Square	Std. Error of the Estimate
.380[a]	.144	-.046	.037

[a] Independent Variable (Constant Predictors) = Intentions and Attitudes toward respirator use.

5.2 Intervention Results

Intervention results are based on observation data obtained from the six weeks of pre- and post-intervention video monitoring. Once all data was obtained on VHS tapes and copied to DVD format for ease in viewing, two observers watched the videos independently. Each observer recorded that data using the following variables:

- Subject Identification
- Day of week for episode
- Day or night shift for episode
- Number of episodes for the subject's shift
- Number of episodes resulting in use of respirators or safe work practice for each subject
- Total time of each subject's episodes (cumulative for each shift)
- Total time of non-use of respirator or safe work practice for each subject (cumulative for each shift)

The results of the video monitoring data are presented in two main sections. The first section reviews inter-rater agreement and reliability in coding the video data. The second explores if differences exist in use of respirators or safe work practices before and after the intervention designed to increase fulfillment of company safety expectations.

5.2.1 Inter-Rater Observations

The researcher was the primary observer. The second observer was a graduate student compensated for time of observations. The primary observer trained the second observer and defined the parameters of the study along with the data to be recorded. Definitions for the above mentioned variables are presented.

- Subject Identification - based on the 41 original subjects labeled as E01 through E41
- Day of week for episode - refers to day of week 1-7 (Monday being 1 and Sunday being 7)
- Day or night shift for episode - refers to day or night shift (1 = day, 2 = night); day shift is from 0700hrs to 1900 hrs; night shift is from 1900 hrs to 0700 hrs.
- Number of episodes for the subject's shift - refers to the number of times the coating station enclosure was opened by that employee or employee in that area with door open. The area is defined as crossing the yellow line outside the enclosure.
- Number of episodes resulting in use of respirators or safe work practices for each subject - refers to number of times coating station enclosure was opened by that employee and resulted in no exposure (do to work practice or respirator use).

- <u>Total time of each subject's episodes (cumulative for each shift)</u> - refers to total time in minutes that coating station enclosure was open.
- <u>Total time of non-use of respirators or safe work practice for each subject (cumulative for each shift)</u> - refers to time in seconds of exposure (employee inside at-coat machine without respiratory protection)

The primary observer was very familiar with the machine and the workers at the machine. Due to the quality of the video, at times it was difficult for the second observer to see who was at the machine enclosure. After data was gathered and entered into the tracking log, the two observers reviewed some specific episodes to verify which worker was actually in the area. As a result, several workers were relabeled in the second observers log.

5.2.1.1 Inter-Rater Agreement and Reliability

To understand the agreement and reliability between the two observers, a generalization coefficient was used to measure absolute difference and reliability between each observation made by the two observers. A G-absolute coefficient of 0.7 and greater is the guideline used in research to show good reliability. In this study, G-absolute equaled 0.311 for a single rater and 0.347 for the average to the two raters. This shows poor reliability. However, this value may be low as a result of the high number of instances where both raters agreed that there was no episode of non-use of respirators or safe work practices. A zero would be entered into the database and calculated as such. While the G-absolute test penalizes one for zeros in the data field, it is best used for the quantitative results such as timed intervals inside the machine enclosure. While other statistical tests such as Cohen's kappa or Scott's pi would not penalize for zeros in the data field, one would be penalized for discrepancies in the quantitative data. If two raters were even off by one second in observations during an episode, this would be viewed as disagreement and exaggerate small discrepancies in the video analysis. A zero in the data would mean that both raters completely agreed that there was no episode of non-use of respirators; however, testing this statistically is not possible.

5.2.2 Pre- and Post-Intervention

To measure the effect of the leadership-based intervention used in this research, video observation data was gathered to view workers behaviors prior to the intervention and after the intervention. The variables observed by the two observers have been listed previously. The video camera was installed on the east wall of the coating machine in order to capture video at one station of the coating machine. It was decided that the camera should be installed several months prior to actual recording in order to decrease workers' perception of the camera. All subjects in the study were informed when the camera was installed. The camera was clearly visible 10 feet up the east wall. Beginning on September 20, 2004, several preliminary recordings were taken to calibrate the location and speed of the camera. Final speed was set at 120-hour mode. On October 4, 2004, the camera was moved to a new location approximately 2 feet down and 5 feet to the right when looking at the wall. This was to get a better view of the west side of the enclosure. The camera remained in place during the entire study. Pre-intervention video monitoring began on July 15, 2005 at 3:35 pm. Approximately three days later, the tape was stopped due to a machine malfunction leading to several days of downtime. The first tape was discarded from the data. A second tape was started on July 18, 2005 at 11:00am. Then commenced the pre-intervention video monitoring. Pre-intervention video monitoring continued during the following dates:

1) Tape 1 – July 18, 2005, 11:00am through July 24, 2005, 1:09am
2) Tape 2 – July 26, 2005, 8:08am through July 31, 2005, 10:13pm
3) Tape 3 – August 1, 2005, 8:30 am through August 6, 2005, 10:44pm.

Following the pre-intervention video monitoring, the pre-intervention questionnaire was administered by the researcher. The questionnaire began August 11, 2005 for Crew 4 and all questionnaires for all crews were completed by August 26, 2005. The leadership-based intervention commenced on August 26, 2005. The leadership-based portion of the intervention was completed on October 28, 2005. On October 28, 2005, the employee-conducted air sampling began. All participants in the study completed the air sampling by November 10, 2005.

All crews completed the questionnaire between January 16, 2006 and January 20, 2006. Post-intervention video monitoring began in earnest on January 20, 2006 at 2:46pm. Post-intervention video monitoring continued during the following dates:

4) Tape 4 – January 20, 2006, 2:46pm through January 25, 2006, 12:31am (clock on recording device failed at this time, 3 episodes following the failure were estimated for duration)
5) Tape 5 – February 7, 2006, 2:15pm through February 13, 2006, 2:01am
6) Tape 6 – February 16, 2006, 4:29pm through February 22, 2006 6:52am.

Several tapes were discarded between Tape 4 and Tape 5 due to recording device failure. This explains the time span between the end of tape 4 and the beginning of tape 5 (approximately two weeks). Tapes 5 and 6 have several days of downtime recordings. No activity on the machine took place during these days. This was due to the scheduled weekend downtime. These downtime days were not counted as part of the three-week post-intervention video monitoring. The six tapes listed above constitute the three weeks of pre- and three weeks of post-intervention video monitoring. Once data was entered into the tracking log, a paired-samples t-test was run to compare pre- and post-intervention use of respirators or safe work practices. Time is the dependent variable for this test. A t-test was run to compare pre- and post-intervention use of respirators or safe work practice for the night shift workers and day shift workers. A paired-samples t-test by crew was used to compare pre- and post-intervention use of respirators or safe work practices between the crews. The repeated measures ANOVA described in the protocol was the recommended statistical test for determining the variability within and between measurements with the independent variable being time. This statistical test was not possible for the results of the video monitoring. The statistical package used to run this data codes missing data for any episode that an operator was not involved. For example, on day 1 subjects 5,6,7 and 12 were observed in the area conducting work at the machine enclosure. However, the other 10 subjects were not seen and thus are counted as missing data. There were too many missing data points. It would be impossible to obtain sufficient data points for this type of observation.

5.2.2.1 Post-Intervention Use of Respirators or Safe Work Practices

To compare use of respirators or safe work practices by coating machine operators before and after the leadership-based intervention, video observation data was used to run paired-sample t-test. The dependent variable is the proportion of time spent in non-use of respirators or safe work practice episodes. The proportion of non-use of respirators or safe work practices decreased from 4.91% prior to the intervention to a proportion of 1.98% after the intervention. In calculating the paired differences, the mean of .02929 is statistically significant (p=.027) Refer to tables 7 - 9.

Table 7. Paired Samples Statistics

	Mean	N	Std. Deviation	Std. Error Mean
Pre-intervention proportion of non-use of respirators or safe work practices	.0491	14	.05518	.01475
Post-intervention proportion of non-use of respirators or safe work practices	.0198	14	.03420	.00914

Table 8. Paired Samples Correlations

	N	Correlation	Significance Level
Pre-intervention proportion of non-use of respirators or safe work practices and Post-intervention proportion of non-use of respirators or safe work practices	14	0.602	0.023

Table 9. Paired Samples Test

	Paired Differences							
				95% Confidence Interval				
	Mean	Std. Dev	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pre-intervention proportion of non-use of respirators or safe work practices – Post-intervention proportion of non-use of respirators or safe work practices	0.02929	0.04407	0.01178	0.00385	0.05473	2.487	13	0.027

As the process on this particular rotogravure printing press evolved, safe work practices may have been deemed the best way to avoid exposure to solvent vapors inside the machine. This evolvement of the use of safe work practices should be taken into consideration when interpreting results of this study. In interpreting the results, it should be concluded that adherence to safe work practices prescribed in the department procedures was the indicator for the statistically significant decrease in the proportion of observations that resulted in non-use of respirators or safe work practices. Video observations proved that respirators were not used at any time during the research timeframe. However, safe work practices were observed including the use of body positions to keep one's head out of the coating enclosure.

5.2.2.2 Comparison of Crews

Four crews work rotating night and day shifts on the coating machine. Each crew consists of 2 to 3 operators. Paired t-test statistics were run for comparing the average pre-intervention proportion of non-use of respirators or safe work practices and the average post-intervention proportion of non-use of respirators or safe work practices. This was tested to understand if there were differences in fulfillment of company safety expectations from one crew to another and to explore those differences. Upon watching the pre- and post-intervention videos, one leader (focus person) who took part in the leadership-based intervention was actually observed not adhering to company safety expectations more than any other operator. The researcher wanted to understand if crew leadership or any other variables made an impact on use of respirators or safe work practices. Due to the very small sample size on each crew, the statistics are extremely unstable making interpretation unreasonable.

5.3 Leadership-Based Intervention Effects

The tool used to understand the effects that this leadership-based intervention had on the workers was a 19 question survey presented after the intervention was complete but prior to the post-intervention video monitoring. To measure the effectiveness, descriptive statistics for the questionnaire and internal consistency and reliability tests were run. Factor analysis for this survey was considered but not possible due to the small sample size.

5.3.1 Descriptive Statistics for Post-Intervention Questionnaire

Thirteen of the 14 subjects completed the post-intervention questionnaire. The one subject who did not complete the questionnaire was in the process of being transferred out the department and was indifferent in completing the questionnaire. The mean and standard deviation for the six-point scale questionnaire were 4.09 and .761, respectively. This indicates that attitudes following the leadership-based intervention were on the positive side of the scale for agreement with the statements in the questionnaire. Of the 13 subjects that completed the post-intervention questionnaire, 10 responded that their supervisor had discussed company expectations for respirator use and following safe work practices with them, 12 indicated that were aware of the chemical concentration level inside the machine enclosure, and 12 responded that they understood the expectations for of protection when inside the machine enclosures.

5.3.2 Internal Consistency Reliability

Cronbach's alpha was used to measure internal consistency for the 19 items in the post-intervention questionnaire. A value of .820 indicates acceptable reliability.

6.0 CONCLUSIONS

The hypothesis of this study was that multifaceted intervention efforts including leadership-based intervention and employee conducted air sampling will increase use of respirators or safe work practices as expected by company procedures.

6.1 OBJECTIVE 1 – Intentions Predicting Behavior

The first objective of this study was to determine if employees' intentions of respirator use are predictive of behavior. The trend toward more respirator use is observed in the data. However, the results were not statistically significant and the hypothesis that intentions will predict behavior was not proven for this study. A similar study indicated that intentions were only partially predictive of behavior.[6] In comparing both studies, many individuals who had seldom worn respirators in the past indicated that they would wear respirators more frequently in the future. The operators may have had difficulty in providing valid estimates of past or intended respirator use. It is possible that some operators reported past use and intended use of respirators according to their perceptions of the researcher's beliefs, even though the questionnaires were self-administered. For this to be a systematic error these same operators would also need to have misrepresented their respirator use in a similar manner. Data compiled from video observations showed that respirators were not used but an increase in use of safe work practices was observed.

6.2 OBJECTIVE 2 – Increasing Use of Respirators and Safe Work Practices

The second objective of this study was to determine if the leadership-based intervention coupled with employee-conducted air monitoring will increase respirator use when operators are inside the coating machine enclosure. Adherence to company expectations based on written procedures was defined as avoiding exposure to organic solvents by wearing a respirator when inside the machine enclosure or by adhering to the safe work practices that avoid entrance into the enclosure. Video data showed that during the six weeks of monitoring work at the coating station, no operator used a respirator. However, adherence to safe work practices that kept operators away from the elevated air concentration of organic vapors inside the machine enclosure increased significantly after the intervention. While a significant increase occurred in the use of safe work practices, the researcher was not able to draw conclusions as to the cause of the increase. This research was intended to be a multifaceted approach. Two questionnaires were used, three different types of leaders were used, and employee conducted air sampling was used. One would argue that the two questionnaires were part of the intervention. The questions were very detailed pertaining to past and intended respirator use. This may have sparked the operators' interest and a decision was made to conform to safe work practices. Video data showed that at no time did an operator wear a respirator. Therefore, since the questionnaires were directed at the use of respirators and not safe work practices, it cannot be concluded that the questionnaires increased the use of respirators. As such, this supports the researchers premise that the questionnaires were not intended to be part of the intervention.

The only leadership intervention strategy that was monitored by the researcher was the closed-door interview with each employee. All employees who participated in this research received the same information regarding expectations from the supervisors. This was verified in the post-intervention questionnaire where 11 of 14 employees indicated they agreed that their supervisor had discussed respirator use with them. There is record that all 14 employees did attend the closed-door interview with their supervisor. This suggests that recall of the interview may have been the reason for employees indicating in the questionnaire that the supervisor did not discuss respirator use with them. Actual frequency and duration of employee-leader interaction regarding the use of respirators was not monitored. The researcher did not know if the department manager, supervisor or focus persons met at all with employees on the machine floor. This was an integral part of the research that was not monitored. As mentioned before, the post-questionnaire tried to answer the question of leadership involvement in the respiratory protection program. This can be deciphered from questions 4, 5, 6 and 9 of the post-intervention questionnaire. The threat message was delivered to all employees in the study during each operator's primary interview with their supervisor. How to avoid the threat was also delivered to each operator in the study. The threat was again delivered to the operators during the employee-conducted air monitoring. The researcher delivered this portion of the intervention. The efficacy message was discussed as well. It may be concluded that the employee-conducted air monitoring had the most effect on employees' decision making to improve adherence to company safety policy regarding the entrance into the coating machine enclosure. Operators had the opportunity to conduct industrial hygiene sampling, read the stain tube and receive direct feedback from a trained industrial hygienist concerning the contaminant concentration inside the enclosure. It is the researcher's opinion that he was considered a credible information resource to the operators. Operators seemed comfortable with the delivery method of the researcher. This may be due to previous industrial hygiene work that the researcher had conducted for the operators in this area. The interpretation of concentration and exposure dose may have been the most influential parts of the intervention. The operators may have been persuaded by the researcher due to the high level of credibility of the source and not because they believed the message. Petty and Cacioppo[45] suggested the people could be persuaded by credibility or attractiveness of the source. When this happens, those accepting the message are said to have processed the message peripherally. This may be due to lack of interest, ability or motivation to fully understand the message.

6.3 OBJECTIVE 3 – Employee Attitudes

The third objective was to describe the ability that a leadership-based intervention affects employees' attitudes. The combined results from the post-intervention questionnaire demonstrated that attitudes toward respirator use requirements tend to be positive and employees do have an understanding of what the requirements for respirator use are for entering the machine enclosure.

As a final note on this leadership-based intervention, in a world where high production pressures may obscure the importance of protecting oneself from occupational hazards, this intervention was shown to not affect production. In fact daily average production output increased as this intervention was ongoing.

Adherence to company respirator use requirements and safe work practices did not get in the way of doing business.

6.4 Future Research

The pre-intervention questionnaire was a major part of this study as it helped draw conclusions about past use and intended use of respirators. The questionnaire asked detailed questions as to the beliefs that employees had toward respirator use. However, the researcher did not explore if the questionnaire could be used as part of the intervention process. Also, the individual questions were not explored from a statistical standpoint. Future research may be able to draw defined conclusions pertaining to the effectiveness of questionnaires that relate to past use and intended use of personal protective equipment.

Future research could also focus on different industrial processes where respirator use is to be used on a more consistent basis. Six weeks of video monitoring at the rotogravure printing press showed sporadic events when respirator use should have been used. The research presented may be more applicable and meaningful to industries where respirator use is more predictive and easily observed.

Research could continue in the area of employee perceptions of leadership involvement in safety. This research did have questions aimed at exploring this research question. However, in-depth discussion and conclusions were not explored.

A significant finding in this research that should lead to future studies pertains to the influence employee-conducted air monitoring had on changing employee behavior with regards to adherence to safe work practices or personal protective equipment use. The importance of employees being able to see direct results should not be underestimated. Various types of direct reading instruments are available as a visual cue to employees. Innovative techniques could be developed to improve employee understanding of concentration and potential exposure and dose.

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Appendix A

Pre-Intervention Questionnaire and Data for all Participating Subjects

Pre-Intervention Questionnaire

Name:____________________________Age_____No. of Years with Company________
No. of Years as a Coating Machine Operator________

Part A:

Please circle the letter that best corresponds with your answer

A.1. In the past, how often did you wear a respirator when working inside the machine enclosure?
1) Never
2) Sometimes (less than 40% of the time)
3) About half the time (40-60% of the time)
4) Most of the time (60-90% of the time)
5) Always (more than 90% of the time)

A.2. How frequently do you intend to wear the respirator when working inside the machine enclosure?
1) Never
2) Sometimes (less than 40% of the time)
3) About half the time (40-60% of the time)
4) Most of the time (60-90% of the time)
5) Always (more than 90% of the time)

Part B:

This part of the questionnaire will be based on a 6-point scale with <u>1 being strongly disagree and 6 being strongly agree</u>. Please circle the number that best corresponds with your answer.

B.1. If I continuously wore a respirator every time I entered the machine enclosure,

then...

1) * The respirator would get in the way of my work. 1 2 3 4 5 6

2) * I would feel uncomfortable performing tasks. 1 2 3 4 5 6

3) * I would have difficulty breathing while performing tasks. 1 2 3 4 5 6

4) * I would feel closed-in, trapped. 1 2 3 4 5 6

5) I would feel better after work. 1 2 3 4 5 6

6) I would be more mentally alert at work (no dizziness or lightheadedness).
1 2 3 4 5 6

7) My nose, throat and lungs would be protected from harmful chemicals.
1 2 3 4 5 6

8) * Other people would think that I was foolish. 1 2 3 4 5 6

9) I would live longer. 1 2 3 4 5 6

10) I would be better able to produce healthy children. 1 2 3 4 5 6

11) I would have less chance of getting cancer. 1 2 3 4 5 6

12) * I would have more chance of having a heart attack. 1 2 3 4 5 6

13) I would have less chance of being in an accident. 1 2 3 4 5 6

14) Airline respirators are the best way to protect myself from harmful chemicals.
1 2 3 4 5 6

*Reverse coded items

Pre-Intervention Questionnaire Data

Question #	Sub. 1	Sub. 2	Sub. 3	Sub. 4	Sub. 5	Sub. 6	Sub. 7	Sub. 8	Sub. 9	Sub. 10	Sub. 11	Sub. 12	Sub. 13	Sub. 14
A.1	2	4	3	2	1	4	2	2	4	3	1	2	--	--
A.2	4	4	4	5	2	5	5	2	5	3	2	2	--	--
B.1	4	3	4	6	4	5	2	5	2	3	6	5	--	--
B.2	1	4	4	6	4	5	1	6	--	3	6	3	--	--
B.3	1	1	5	1	3	6	1	1	6	2	2	1	--	--
B.4	1	2	3	1	4	6	1	2	4	2	5	1	--	--
B.5	4	5	1	1	4	2	5	2	3	1	2	3	--	--
B.6	3	5	2	1	4	2	5	2	5	1	2	3	--	--
B.7	4	6	1	6	5	1	6	5	2	3	5	4	--	--
B.8	6	4	5	1	3	5	2	2	6	1	1	3	--	--
B.9	5	3	1	1	5	2	3	4	2	3	1	6	--	--
B.10	1	3	1	1	4	2	3	6	3	3	1	6	--	--
B.11	3	2	1	1	5	1	5	4	4	3	1	4	--	--
B.12	4	5	3	1	4	1	1	5	3	1	1	3	--	--
B.13	4	5	3	1	3	1	3	6	5	3	1	4	--	--
B.14	4	3	1	4	5	2	6	2	2	3	6	4	--	--

Appendix B

Post-Intervention Questionnaire and Data for all Participating Subjects

Name:____________________________Age______No. of Years with Company________
No. of Years as a Coating Machine Operator________

This part of the questionnaire will be based on a 6-point scale with **<u>1 being strongly disagree and 6 being strongly agree</u>**. Please circle the number that best corresponds with your answer.

	1. My supervisor says a good word whenever he/she sees me wearing my respirator according to the safety rules	1 2 3 4 5 6
	2. My focus person says a good word whenever he/she sees me wearing my respirator according to the safety rules	1 2 3 4 5 6
	3. My manager says a good word whenever he/she sees me wearing my respirator according to the safety rules	1 2 3 4 5 6
	4. My supervisor has discussed respirator use with me.	1 2 3 4 5 6
	5. My focus person has discussed respirator use with me.	1 2 3 4 5 6
	6. My manager has discussed respirator use with me.	1 2 3 4 5 6
	7. I am more willing to listen and do what my supervisor says regarding respirator use than my focus person.	1 2 3 4 5 6
	8. I am more willing to listen and do what my supervisor says regarding respirator use than the manager.	1 2 3 4 5 6
	9. My supervisor has approached me during work to discuss respirator use.	1 2 3 4 5 6
	10. My supervisor gets annoyed with any worker ignoring respirator safety rules.	1 2 3 4 5 6
	11. My supervisor watches more often when a worker has violated respirator safety rules.	1 2 3 4 5 6
*	12. As long as there is no accident, my supervisor doesn't care if a respirator is worn when it should be.	1 2 3 4 5 6
*	13. Whenever production pressure builds up, my supervisor wants us to work faster, rather than by the safety rules.	1 2 3 4 5 6
*	14. My supervisors pays less attention to safety rules regarding use of respirators than other supervisors in this company.	1 2 3 4 5 6
*	15. My supervisor only keeps track of major safety problems and overlooks routine use of respirators.	1 2 3 4 5 6
*	16. As long as work remains on schedule, my supervisor doesn't care if respirators were worn to achieve it.	1 2 3 4 5 6
	17. I am aware what the chemical exposure levels are inside the machine enclosures.	1 2 3 4 5 6
	18. Knowing what the chemical exposure levels are inside the machine enclosure has increased my use of respirators.	1 2 3 4 5 6
	19. I understand the expectations of respirator use inside the machine enclosures.	1 2 3 4 5 6

*Reverse coded items

Post-Intervention Questionnaire Data

Question #	Sub. 1	Sub. 2	Sub. 3	Sub. 4	Sub. 5	Sub. 6	Sub. 7	Sub. 8	Sub. 9	Sub. 10	Sub. 11	Sub. 12	Sub. 13	Sub. 14
1	6	3	4	2	3	5	2	4	--	5	5	6	1	6
2	5	4	4	1	5	4	4	4	--	5	5	6	1	6
3	5	3	3	1	3	1	1	4	--	5	3	6	1	6
4	5	1	4	4	3	4	4	4	--	5	4	6	1	6
5	5	5	6	6	5	6	6	5	--	5	5	6	1	6
6	3	2	3	1	3	1	1	4	--	5	3	6	1	6
7	6	1	4	1	4	1	1	2	--	1	5	6	1	4
8	6	3	6	1	4	3	6	2	--	1	5	6	1	4
9	5	1	3	1	2	5	2	4	--	5	4	6	1	6
10	5	3	5	6	3	4	6	5	--	4	1	6	3	4
11	3	5	4	5	3	4	5	5	--	3	1	6	3	4
12	4	3	1	1	4	1	1	2	--	2	2	6	1	1
13	1	3	2	3	3	1	1	1	--	1	2	6	4	1
14	2	4	1	1	3	1	1	1	--	1	2	5	3	1
15	2	3	3	1	2	1	1	2	--	1	5	6	4	1
16	2	4	1	1	2	1	1	2	--	1	2	6	6	1
17	5	6	5	6	3	6	4	5	--	5	5	4	5	6
18	5	4	6	1	2	6	5	4	--	5	2	4	5	6
19	6	6	6	6	2	6	6	6	--	5	5	4	6	6

Appendix C

Pre-Intervention Video Data for all Participating Subjects

Pre-Intervention Video Data, Subjects 1 to 7

Day No.	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6		Subject 7	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1									1	0	1	0	1	0
2	2	85	1	0							0	4		
3	1	0	1	0			3	10	1	61				
4							2	0						
5			1	0			1	0					3	55
6									1	0				
7									1	32			3	0
8			1	5	3	0	3	0						
9			1	0			1	7						
10														
11														
12	3	236	1	0			1	0						
13	5	359	6	417			7	45					1	0
14														
15														
16											2	41	3	98
17							2	0						

A - # of episodes (operator interface with machine at station enclosure)

B – Duration of non-use of respirators or safe work practice episode (in seconds)

Pre-Intervention Video Data, Subjects 8 to14

Day No.	Subject 8		Subject 9		Subject 10		Subject 11		Subject 12		Subject 13		Subject 14	
	A	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**
1									2	0				
2									1	0	1	0	1	0
3			3	209							1	0	1	0
4					2	7			1	0			2	0
5			1	0										
6					1	13	1	25						
7											2	0		
8														
9	2	7									2	0		
10	1	0			1	0	2	213	1	0	2	0		
11					1	0	2	46	1	0				
12					1	63	2	18	2	37				
13														
14							2	64	1	0				
15	1	5	2	305					1	0				
16	1	5									3	0		
17														

A - # of episodes
B – Duration of non-use of respirator or safe work practice episode (in seconds)

Appendix D

Post-Intervention Video Data for all Participating Subjects

Post-Intervention Video Data, Subjects 1 to 7

Day No.	Subject 1		Subject 2		Subject 3		Subject 4		Subject 5		Subject 6		Subject 7	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1											2	0	1	0
2			2	0							2	2	1	0
3			3	0	2	0	1	0			1	0	1	0
4	1	11					1	0	1	0				
5	1	0							1	0				
6							1	36						
7														
8	1	0												
9	1	0									2	0	1	0
10					1	0	1	0						
11														
12											1	0		
13														
14	3	19												
15														
16														
17														

A - # of episodes
B – Duration of non-use of respirators or safe work practice (in seconds)

Post-Intervention Video Data, Subjects 8 to14

Day No.	Subject 8		Subject 9		Subject 10		Subject 11		Subject 12		Subject 13		Subject 14	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1														
2					2	7								
3														
4														
5							1	15						
6											1	0	1	0
7							1	22	1	0				
8									1	0	1	0		
9									1	0				
10														
11							1	33	1	0				
12	1	0			2	67								
13			2	15										
14			1	0			1	0	1	16				
15														
16														
17														

A - # of episodes
B – Duration of non-use of respirators or safe work practice episode (in seconds)