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Controlling Lead Exposure During the Process of Cleaning Aviation Spark Plugs

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CONTROLLING LEAD EXPOSURE DURING THE PROCESS OF CLEANING
AVIATION SPARK PLUGS

THESIS

Presented to the Graduate Committee of the
Embry-Riddle Aeronautical University
in Partial Fulfillment of
the Requirements

For the Degree

Master of Science in Safety Science

By

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May, 2003

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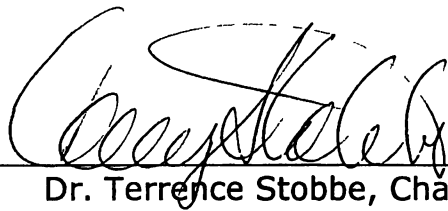
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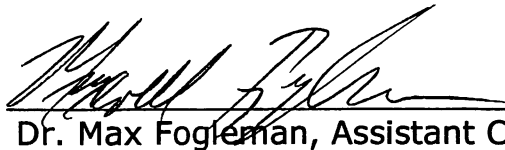
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"Happiness comes when your work and words are of benefit to yourself
and others" *Buddha*

Thanks to Terry Stobbe for the guidance and patience to help me
see this project through to the end.

ABSTRACT

CONTROLLING LEAD EXPOSURE DURING THE PROCESS OF CLEANING AVIATION SPARK PLUGS

Curtis E. Beers

This study examines the process of removing lead bromide from aircraft spark plugs and the health hazards associated with the present method of cleaning the lead bromide accumulation from aviation spark plugs. Aviation maintenance technicians can be inadvertently exposed to lead while cleaning the lead bromide accumulation from the spark plug electrode during scheduled engine maintenance.

This study explores controlling the lead bromide particulate matter after it is removed from the spark plug electrode. Various control methods and/or procedural changes that may be employed to control the spread of lead bromide dust throughout the shop environment and the prevention of employee exposure to lead will also be explored.

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CHAPTER I

INTRODUCTION

This paper examines the process of cleaning lead bromide accumulation from aircraft spark plugs and the potential lead exposure hazards associated with the cleaning process. The lead bromide accumulates on the spark plug electrodes as a result of tetraethyl lead and ethylene dibromide being added to 100 low lead avgas (Chevron, 2002). The tetraethyl lead and the ethylene dibromide react with each other during the combustion process to form lead bromide (Chevron, 2002). The tetraethyl lead is added to the fuel as an anti-knock agent. The ethylene dibromide is added as a scavenging agent to react with the tetraethyl lead and facilitate the removal of the lead byproduct through the exhaust that is formed during combustion (Chevron, 2002). Not all of the tetraethyl lead and ethylene dibromide in the fuel and air mixture completely react during combustion due to variables in the combustion process (Ethyl Corp., 1951). This incomplete reaction results in some lead bromide residue remaining behind in the combustion chamber and accumulating on the spark plug electrode (Figure 1).



Figure 1. Spark Plug with Lead Bromide Accumulation After Fifty Hours of Time in Service

Thomas Midgley Jr. discovered the anti-knock properties of tetraethyl lead on December 9, 1921 while he was conducting research for Charles Kettering to find a suitable fuel additive that would prevent engine knock (Kitman, 2000). It was found that very small quantities of tetraethyl lead could treat large quantities of fuel. As little as two milliliters of tetraethyl lead could treat one gallon of gasoline (Ethyl Corp., 1951). Other fuel additives and anti-knock supplements were available, such as ethyl alcohol or methyl alcohol; however, the people funding the research could not patent the alternatives (Kitman, 2000). The patenting of tetraethyl lead represented a huge potential moneymaker for those funding the research so the alternative anti-knock agents fell in to obscurity (Kitman, 2000).

Lead and lead compounds such as inorganic lead bromide are recognized as toxic elements and hazardous wastes due to the reproductive, physical, and neurological damage created by exposure to minute amounts measured in $\mu\text{g}/\text{dL}$ (micrograms per deciliter of blood). Inorganic lead salts consist of lead compounds such as lead bromide that do not contain carbon but do include elemental lead. Organic lead refers to lead compounds, which contain carbon such as tetraethyl lead or tetramethyl lead.

The fact that tetraethyl lead and tetramethyl lead were banned as an automotive fuel December 31, 1995 by the Environmental Protection Agency (EPA, 40 CFR Part 80) does not mean that the threat of lead poisoning from leaded fuel byproducts and its hazards have suddenly disappeared from the work place (E.P.A. 1996).

Presently, general aviation uses leaded fuel that is commonly referred to as 100LL AVGAS for powering its fleet of piston driven aircraft. Due to a lack of a suitable alternative for tetraethyl lead, tetraethyl lead continues to remain the primary anti-knock additive in 100LL AVGAS (Ethyl Corp., 1951).

Lead bromide accumulates on the electrodes of spark plugs of aircraft engines using leaded Avgas during normal operation and usage. The lead bromide is present on the spark plugs and in the combustion chamber due to the addition of the anti-knock additive tetraethyl lead (Ethyl Corp., 1951).

A rich fuel to air mixture ratio lowers the combustion chamber temperature. The spark plug electrode is a protrusion in the combustion chamber and a heat sink. This combination accelerates the spark plug fouling problem from lead bromide accumulation (NACA, 1945).

The mechanics performing maintenance on piston powered aircraft presently face a lead exposure hazard associated with the use of leaded fuel and the combustion byproducts of the of leaded fuel used to power these types of aircraft. The lead bromide accumulation is removed from the spark plugs by mechanics during the scheduled maintenance at intervals prescribed by the maintenance program or sooner as required.

The night shift mechanics perform the spark plug reconditioning process during fifty-hour progressive inspections. The night shift performs the fifty-hour maintenance tasks since the aircraft are in use during the day for student pilot training. When the aircraft enters the maintenance area for fifty-hour maintenance, the mechanic removes the engine cowling and the upper set of spark plugs (aircraft piston engines have two spark plugs per cylinder) to perform a compression test of the engine.

The majority of aircraft engines used to power the general aviation fleet are predominately four and six cylinder engines. A dual source of ignition is required by the federal aviation regulations; therefore, a four-cylinder aircraft engine will have eight spark plugs per engine.

After the compression test is completed, the mechanic removes the bottom set of spark plugs and places them in a carrying rack to protect them from damage during transportation between workstations. The mechanic then proceeds to the first step of the spark plug cleaning process.

The spark plug cleaning process is performed at two fixed locations in the maintenance facility. The spark plug cleaning bench is the first stop for the removal of the large accumulation of lead bromide matter. The second location is the media blasting cabinet.

The first step of the spark plug cleaning process is to remove the large accumulations of lead bromide concretion from the spark plug electrode and the area surrounding the electrode by using the Champion Spark Plug Vibrator Cleaner (Figure 2).



Figure 2. The Champion Spark Plug Cleaner

The mechanic holds the spark plug against the cleaning blades of the unit and activates the cleaning action by depressing the red button on top of the unit (Figure 3).



Figure 3. Mechanic Demonstrating the First Step of the Cleaning Process

Approximately ninety percent or more of the lead bromide accumulation is removed from the electrode area of the spark plug during this step. Some of the lead bromide being agitated free from the electrode area becomes fine lead dust and is suspended in the air.

A simulation of the lead bromide removal process (Figure 4) demonstrates that the small particulate matter released from the first step of the spark plug cleaning process can become airborne as a result of the cleaning tongs agitating the matter free from the spark plug electrode. The person performing the spark plug cleaning task can inhale the lead bromide dust that is being removed from the electrode area. The performance of this step represents a source of lead exposure.



Figure 4. Simulated Lead Bromide Removal Demonstrating the Visible Airborne Particles Being Released During Cleaning

The lead bromide that has accumulated in the electrode chamber is mechanically vibrated loose from the electrode and falls to the work surface below the cleaning unit. Some of this lead bromide also becomes airborne. The brown matter on the workbench top is lead bromide residue from the cleaning process. The employee receives a lead exposure from the cleanup of the workbench (Figure 5).



Figure 5. Spark Plug Cleaning Bench

The second step in the spark plug cleaning process is the abrasive media blasting cabinet located in a room adjacent to the parts room. The mechanic places the spark plugs in an abrasive media-blasting cabinet to remove any residual lead bromide from the electrode area (Figure 6). The abrasive media blasting cabinet uses a fine abrasive media propelled by compressed air to dislodge the remaining lead bromide that was not removed by the vibrator cleaner (Figure7).

The vacuum system used by the abrasive media-blasting cabinet is not a High Efficiency Particulate Air (H.E.P.A.) system. An airborne lead exposure to the person performing the blasting process takes place during this step of the spark plug cleaning process. Additionally, the people working in the parts room receive a collateral airborne lead exposure due to their immediate proximity to the abrasive media-blasting process.

Some mechanics also use compressed air to blow the spark plugs clean outside of the abrasive media blasting cabinet facing the shop floor (Figure 8). Note that the mechanic is not using a respirator. A lead exposure hazard exists at this step of the cleaning process.



Figure 6. The Abrasive Media Blasting Cabinet with Spark Plugs Placed Inside for Cleaning

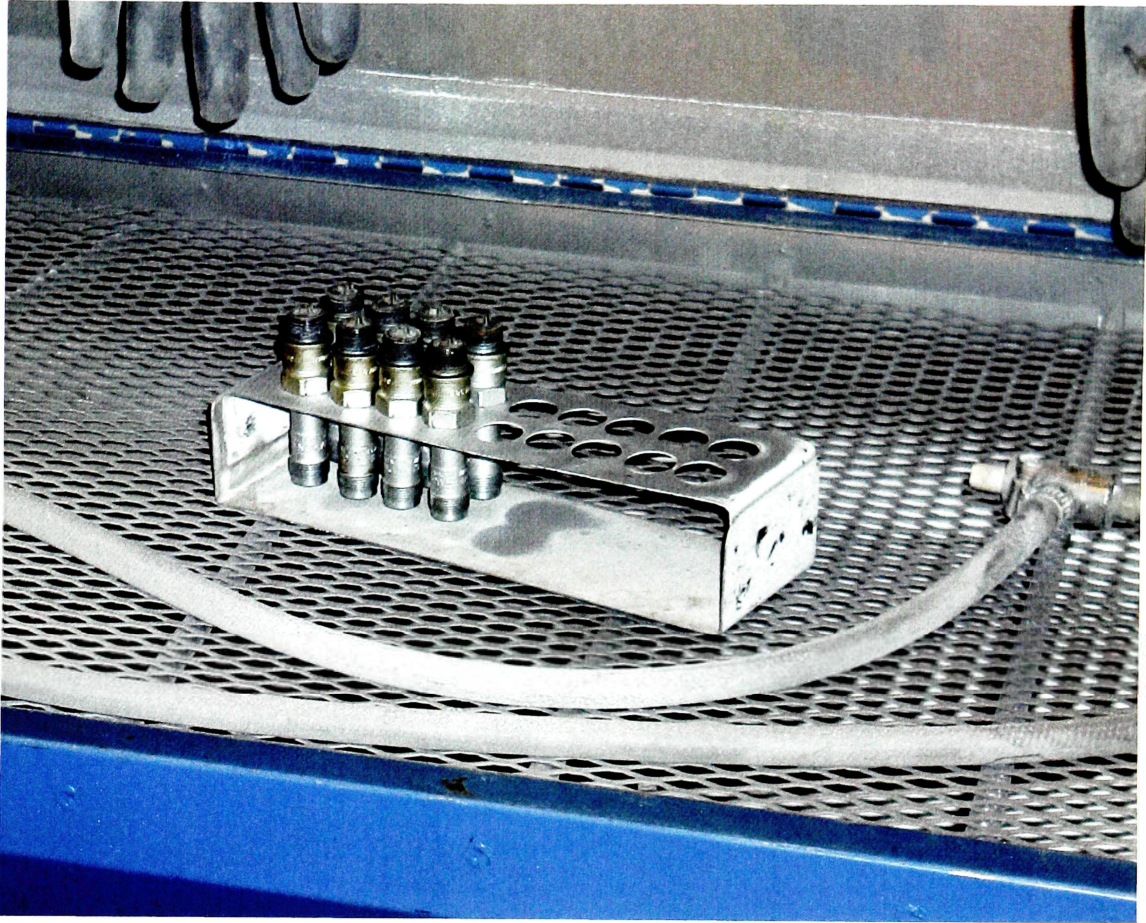


Figure 7. A Close Up of the Inside of the Abrasive Media Blasting Cabinet with the Spark Plugs Ready for Cleaning

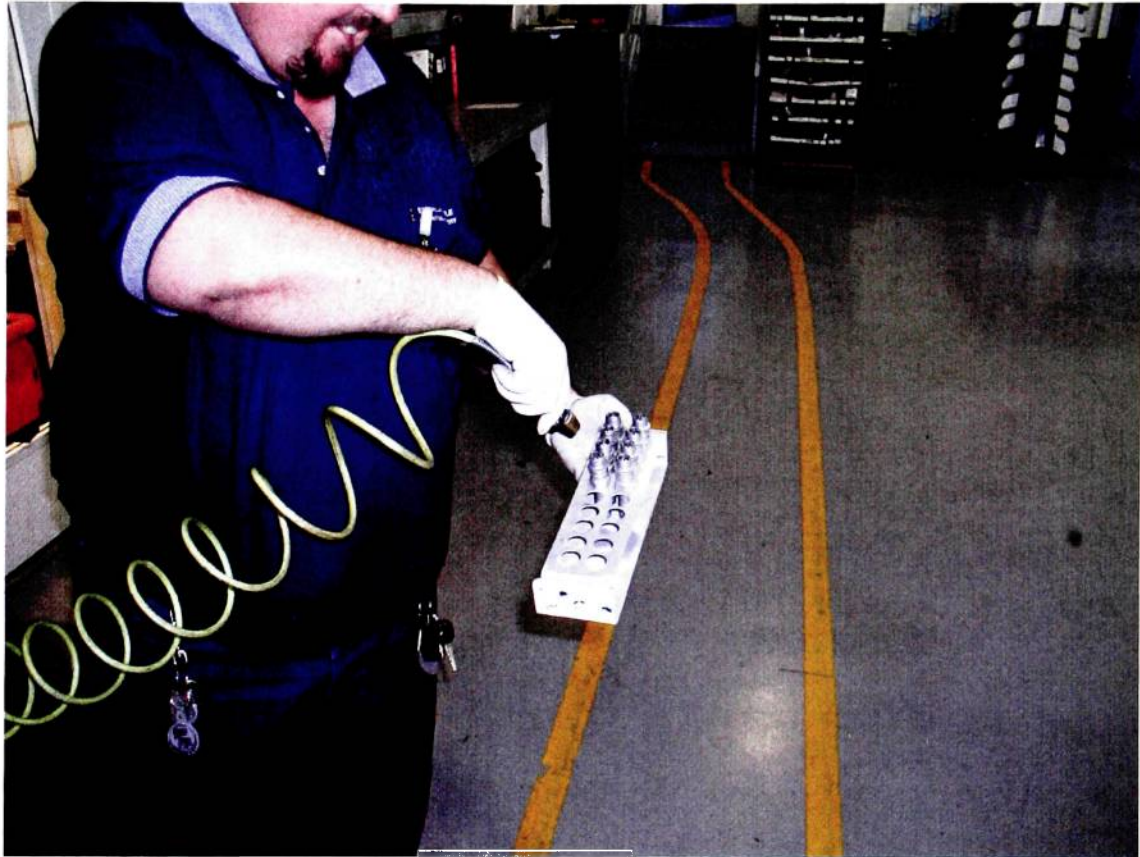


Figure 8. Mechanic Removing Residual Blasting Media With Compressed Air

Based on a thorough literature review, there is no federal regulation or government publication that prescribes a process or a procedure for the cleaning of aircraft spark plugs. F.A.A. Advisory Circular 43.13-1B/2A sections 8-15 (c) paragraph 2 refers the mechanic to the manufacturers recommended procedures for the cleaning and gapping aircraft spark plugs (FAA, 1998).

Champion Aviation Products Service Manual AV6-R page 13, 14, 15 describes the procedure for cleaning the firing end of the spark plugs. The only admonishment stated in the procedure for protecting the service person performing the task of cleaning spark plugs is a small disclaimer that reads (Champion, 2001):

“CAUTION: If you are cleaning a large number of spark plugs in a small restricted area, wear a mask to prevent inhaling abrasive dust”.

The order of the steps in the spark plug cleaning process is consistent among mechanics; however, the manner in which each mechanic performs each step varies with each individual mechanic. Depending upon the mechanic, after the completion of the abrasive media blasting step, the spark plugs may be blown off with compressed air inside of the abrasive media blasting unit or they may be removed from the abrasive media blasting cabinet and blown off out on the shop floor.

After the spark plugs have been through the abrasive-media blasting step, some mechanics opt to rinse the spark plugs off with 100 octane low lead avgas or alcohol. There is no consistent explanation for performance of this additional step after the spark plugs have been blown off with compressed air.

The lead bromide residue can possibly be transported and dispersed throughout areas of the workshop by airborne means such as:

- The use of compressed air
- Drafts and air currents from the hangar doors being open
- Cooling fans during warm weather
- Heating air ventilation
- Cleanup of the workplace area after the spark plug cleaning task is completed

The lead bromide accumulation that is removed from the spark plugs during the cleaning process is uncontained and introduced into the workplace environment as a fine particulate powder that becomes airborne and is subsequently dispersed throughout the workshop. The pulverized lead bromide residue liberated from the spark plug electrode can be inhaled or ingested by the mechanics during the course of performing the spark plug cleaning task and during the clean up associated with the surrounding work place areas.

The variability of the mechanics performing each step of the spark plug cleaning procedure introduces the possibility for a lead exposure to an employee or a collateral lead exposure hazard happening to a family member by a mechanic taking lead dust home with them at the end of a shift. A thorough review of the literature found no published procedure mandated by the management for the employees concerning personal protective equipment. The mechanics are provided with work attire suitable for the task of aircraft maintenance; however, there are no provisions for the employees to shower and change clothing prior to the end of a shift before they go home. Also, there is no laundry service to collect the lead contaminated clothing worn by the mechanics.

As a result of this lack of changing facilities and showers, it is very possible that the employees are transporting lead dust home to their families. The resulting lead exposure to employees introduces potential lost time from the workplace and a plethora of bioaccumulative toxic effects associated with chronic lead exposure.

The legal ramifications associated with a known lead hazard for the employer could represent an inestimable cost resulting in fines from OSHA and the settlement of civil lawsuits from the employees and their families.

Observations of the maintenance facility conducted by the researcher and observations of the maintenance practices enlisted by the mechanics suggested that the aircraft mechanics are receiving a lead exposure as a result of the spark plug cleaning process presently used by Embry-Riddle Aeronautical University.

It is hypothesized that:

- The process used by the mechanics to clean spark plugs is creating a lead exposure for mechanics that exceeds permissible OSHA levels
- The process used by the mechanics to clean spark plugs has introduced lead dust into the maintenance facility that could represent a lead exposure hazard when employees clean work areas

It is the intent of the researcher to demonstrate that the spark plug cleaning process currently in use and the lack of procedural control is resulting in lead bromide being inhaled as it is released from the spark plug cleaning process.

It is also the intent of the researcher to prove the hypotheses that the process used by the mechanics to clean spark plugs is creating a lead exposure for mechanics that exceeds permissible OSHA levels by personal air sampling of the mechanics.

The researcher intends to prove that the process used by the mechanics to clean spark plugs has introduced lead dust into the maintenance facility that could represent a possible lead exposure hazard when employees clean the work area by evaluating the lead hazard in the aircraft maintenance shop environment through the use of qualitative spot sampling and quantitative wipe sampling of the hangar environment.

The sampling will be performed in steps. If significant numbers of the spot test sample indications are positive, the researcher will then conduct quantitative wipe sample testing of horizontal surfaces to quantify the presence of lead. If the wipe sample data supports the presence of high levels of lead the researcher will test employees for exposure to airborne lead during the process of cleaning the spark plugs through the use of air sampling.

CHAPTER II

REVIEW OF RELEVANT LITERATURE AND RESEARCH

In order to understand an epidemic it is paramount that one understands the culture in which the epidemic occurs. Conversely, by studying an epidemic in detail, it reveals a great deal about the culture and society. Because of its industrial and commercial origins, lead poisoning makes an excellent case study for a researcher. According to Warren (2000), the cause of lead poisoning is clear: "it is a plague of our own creation".

The health related problems with lead exposure received little attention in ancient times since acute lead poisoning tended to be an occupational hazard and normally limited to workers that were usually slaves. The Baltimore Lead Testing Institute (1998) provided a chronological history of mankind's dangerous affair with lead. The first known lead-containing object was a statue found in Turkey that dates from 6500 B.C. Similar decorative artifacts have been found in other civilizations, including a carved statue from the Osiris Temple in Egypt that has been dated 3500 B.C. Lead was also routinely used in commerce and found in many ancient coins. Early Chinese coins were made substantially from lead and Greek and Roman coins were made of bronze, which contains up to 30% lead by weight (The Baltimore Lead Testing Institute, 1998).

Lead was also routinely used in commerce and found in many ancient coins. Early Chinese coins were made substantially from lead and Greek and Roman coins were made of bronze, which contains up to 30% lead by weight (The Baltimore Lead Testing Institute, 1998).

One of the first reported lead poisoning cases occurred in 370 B.C. Hippocrates described a severe attack of colic (upset stomach) in a man who extracted metals. Hippocrates recognized lead as a cause of the symptoms. Unfortunately, lead poisoning as a disease received little attention in ancient times. When occupational lead poisoning occurred, it was ignored because most workers were slaves (Tuormaa, 1995).

Pliny the Elder, an ancient Greek, recorded the symptoms of chronic lead poisoning among those who worked with it during the smelting process. The symptoms reveal that workers were suffering from hallucinations and diminished pallor of the skin. Romans used lead as utensils for eating, vessels for storing wine and as a sweetener for their wine drinks called *sapa* which was in reality lead acetate. As a result, there was a high rate male infertility and stillbirths. (Peterson & Hermes, 2001 and Stobbe, 2003).

Bernardino Ramazzini, the father of occupational medicine, wrote in 1700 A.D. of fifty-four different occupations associated with lead poisoning and described some of them in the section concerning potters and printers (Finigan, 1997). Ramazzini stated that:

During this process (i.e., potting) or again when they use tongs to daub the pots with molten lead before putting them into the furnace, their mouths, nostrils and the whole body take in the lead poison that has been melted and dissolved in water. Hence, they are soon attacked by grievous maladies. First their hands become palsied, they then become paralytic, splenetic, lethargic and toothless so that one rarely sees a potter whose face is not cadaverous and the color of lead." With regard to treatment of workers, Ramazzini noted, "it is hardly ever possible to give them any remedies that would completely restore their health for they do not ask for a helping hand from the doctor until their feet and hands are totally crippled and their internal organs have become very hard and they suffer from another drawback. I mean they are very poor.

Today's victims often suffer from the same drawbacks (Finigan, 1997).

As civilization moved from the Mediterranean into Western Europe, cases of lead poisoning began to show up among workers who were involved in making stained glass.

The process of making stained glass included the use of lead salts to color the glass. This resulted in many deaths that could be directly attributed to the worker's exposure to lead (Warren, 2000).

Lead is still used today throughout the world as a pigment for coloring glass. It improves the clarity of the glass and facilitates the cutting of leaded crystal (Peterson & Hermes, 2001).

Benjamin Franklin *The Franklin Lead Letter* reported the impact of lead poisoning in Colonial America when he wrote about "the dangles" while he apprenticed in a print shop in 1724. The dangles was an extremely debilitating paralysis of the hands that caused the hands to dangle from the wrists of print shop workers for the rest of their lives (Franklin, 1786).

Another popular use of lead was as the pigment in oil-based paint. The process included the mixing of white lead powder, linseed oil and turpentine to make white lead base paint. The lead hazard only exists when the lead carbonate powder is inhaled prior to mixing, wet paint is in contact with skin tissue, or when the paint is dry sanded after the paint is then applied. The groups that were predominately affected were the painters who applied the paint, workers who sanded

the dry paint, and children who ingested paint chips from gnawing on their crib rails. The reason that children ate the paint was because they were teething and the lead carbonate produced a sweet taste when they chewed on the crib rails (Warren, 2000).

Dr. Alice Hamilton, one of the country's foremost experts on lead during the first half of the 20th Century, said she doubted that any effective measures could be implemented to protect the general public from the hazards of widespread use of leaded gasoline. "You may control the conditions within a factory," she said. "But how are you going to control the whole country?" In the early 20th, century in the U. S., Hamilton led efforts to improve industrial hygiene. She observed industrial conditions first hand and startled factory managers, state officials, and mine owners with evidence that there was a correlation between worker illness and their exposure to toxins. She also presented definitive proposals for eliminating unhealthy working conditions (Hamilton, 1943, reissued, 1995).

The Secret History of Lead is a chronological documentation of the discovery and incorporation of tetraethyl lead into motor fuels for the anti-knock value that is contained in the molecular structure of tetraethyl lead. The author documents the political and corporate history of tetraethyl lead and the alternatives to tetraethyl lead that existed at the time.

The author described how the parties that were funding the research suppressed other anti-knock chemicals due to their inability to patent them and glean tidy profits from the sales of tetraethyl lead, which is why tetraethyl lead was chosen over other anti-knock additives.

Aviation Fuels and their Effects on Engine Performance (Ethyl Corp., 1951) published after World War Two described the desired properties of aviation fuel and the operation ranges that it was tested under. Aviation gasoline is a mixture of components that boil over a wide range of temperatures. The text explained why tetraethyl lead was advantageous for aircraft fuel and why other anti-knock additives are not used. The text explained the properties of the various aromatic hydrocarbons that were blended to create avgas and the individual properties associated with them.

High-octane aircraft fuels have mission specific combustion behaviors and are often compared to automotive fuel. This analogy is fallacious reasoning. High-octane avgas must endure a range of temperature extremes and atmospheric variation while retaining consistent vapor properties throughout that range of temperatures. The Reid Fuel Pressure Test Bomb was the device used to test the vapor range of avgas. The test determined the tendency for fuel to vapor lock at a given temperature and pressure (Ethyl Corp., 1951).

The use of tetraethyl lead in aviation fuel as an indispensable anti-knock agent was hailed as an essential additive for controlling detonation in the combustion chamber. This came as no surprise due to the fact that the Ethyl Corporation issued the publication during the peak of leaded gas consumption. The Ethyl Corporation was a major manufacturer of tetraethyl lead. The publication described the lead bromide accumulation on spark plugs and how it becomes greater when the fuel air mixture was rich and not at its optimum combustion ratio (Ethyl Corp., 1951).

Under most circumstances an optimum ratio of 1 pound of air to .08 pounds of fuel yields the most power without destructive engine knock occurring, or put another way, depending upon the compression ratio, between fifteen to seventeen parts of air by weight to one part fuel weight produces maximum power (Ethyl Corp., 1951).

The studies conducted by the *National Advisory Committee for Aeronautics* at the Aircraft Research Laboratory in Cleveland, Ohio examined the rate of accumulation and the deterioration of engine performance associated with the build up of lead on the electrodes of the spark plugs.

Engine operating conditions affected the rate of accumulation and the rate of accumulation decreased as the deposit mass increased.

The deposit mass was subject to movement as the lead bromide became molten and was subjected to gravity and chamber flow forces within the combustion chamber (NACA, 1945).

FAA Advisory Circular 43.13-1B/2A chapter 8-15 (1998) describes the desired properties expected of an aircraft spark plug and the failure modes of the spark plugs when improperly used or installed. The advisory circular does not provide any direction in the area of spark plug cleaning however the circular refers the reader to the manufacturers recommended maintenance procedure.

The *Champion Aviation Service Manual AV6-R* is the manufacturers publication for the recommended servicing of spark plugs. The manual provides a general overview of the types of spark plug fouling and the service limits and cleaning procedures associated with maintaining aircraft spark plugs (Champion, 2001).

The *Chevron Aviation Fuel Review (FTR-3, 2003)* briefly describes the function of tetraethyl lead as an anti-knock additive to aviation fuel and its conversion to lead oxide during the combustion process. Ethylene dibromide is added as a lead scavenger to react with the lead oxide forming lead bromide. The incomplete reaction of the lead oxide with the ethylene dibromide results in some lead bromide being deposited on the spark plugs and in the combustion chamber.

Because these compounds are volatile, they are exhausted from the engine with the rest of the combustion products. Just enough ethylene dibromide is added to react with all of the lead. (Chevron FTR-3, 2002) makes the following statement about tetraethyl lead:

The most important avgas additive is tetraethyl lead. It is added as part of a mixture that also contains ethylene dibromide and dye. Ethylene dibromide acts as a scavenger for lead.

When avgas is burned in an engine, the tetraethyl lead is converted to lead oxide. Without a scavenger, lead oxide deposits would quickly collect on the valves and spark plugs. If the deposits become thick enough, they can damage the engine. Ethylene dibromide reacts with the lead oxide as it forms and converts it to a mixture of lead bromide and lead bromides.

Because the reaction does not go to completion, a small amount of lead oxide deposit is found in the cylinders of aircraft piston engines (p. 2).

The health effects from inhalation exposure of lead are detailed in *Toxicological Profile for Lead*. (1999). The absorption and retention of lead in adults and children are explained in this document.

About 99% of the lead that is taken into a normal healthy adult body will leave the body in the form of waste over the period of a couple of weeks but, only about 33% of the lead taken into the body

of a child will leave the child's body in the form of waste. Under conditions of continued exposure not all of the lead that enters the body will leave in the urine and feces. This can result in the accumulation of lead in the body tissues most notably the bone. The lead accumulates in the soft tissues first such as the blood, liver, and kidneys. After being released from the soft tissues the lead is again picked up and stored in the bone mass due the same molecular valence between calcium and lead *Toxicological Profile for Lead*, (1999).

Based on current studies of inhaled lead in adult humans, between thirty and fifty percent of inhaled airborne lead is deposited in the respiratory tract and absorbed into the blood stream within ten hours. (EPA, 1986).

Lead has no nutritional value in the human body as a vitamin or a mineral. Lead is not transformed or metabolized into other compounds inside of the body. It is retained by the body and accumulates in the soft tissues and is eventually stored in the bones (Webelements, 2003)

A byproduct of leaded fuel combustion is lead bromide and the California air toxics program published findings in September of 1997 listing lead bromide as having a greater water solubility than metallic lead or lead oxide (.8441 grams per 100 milliliters of water at 25

degrees Celsius) and is therefore, more easily assimilated into the body after ingestion or respiration compared to lead oxide, see Appendix A. Although different lead species (e.g., lead oxide, lead sulfide, lead bromide, etc.) are assimilated into the body and absorbed to varying degrees following inhalation, all are capable of causing adverse health effects once they reach sensitive body tissues (CATP, 1997).

The adverse health effects of lead poisoning manifest themselves differently depending upon the type of exposure. There are two types of exposure: chronic long-term exposure and acute short-term exposure. The source of chronic long-term exposure to lead can be more difficult to diagnose due to the inability to specifically pinpoint the source of exposure. Chronic long-term lead exposure can lead to paralysis of the extremities, hearing loss, tooth loss, and damage to liver and kidneys. Neurological damage and impairments such as seizures, mental retardation, and behavioral disorders are also associated with lead exposures (OSHA, 2001).

When lead is scattered in the air as a dust, fume or mist it can be inhaled and absorbed through you lungs and upper respiratory tract. Inhalation of airborne lead is generally the most important source of occupational lead absorption. One of the major targets of lead toxicity in adults is the nervous system, including both the central

and peripheral nervous systems. Lead damages the blood-brain barrier and, subsequently, brain tissues. Severe exposures resulting in BLLs (blood lead levels) $> 80 \mu\text{g/dL}$ may cause coma, encephalopathy, or death (CFR 1910.1025, 1998).

Acute short-term exposure to lead is more easily identified because the symptoms of acute lead poisoning manifest themselves rapidly and the source of exposure is usually easier to identify. Acute short-term exposure to high levels of lead can cause a metallic taste, abdominal pain, vomiting, diarrhea, convulsions, coma or even death (CFR 1910.1025, 1998).

Historically, the most severe damage to the peripheral nervous system from high, chronic, workplace exposures to lead (two or more times higher than the current OSHA Permissible Exposure Limits [PEL] of $50 \mu\text{g/m}^3$) resulted in local paralysis described as "wrist drop" or "foot drop" (CFR 1910.1025, 1998).

Because of the improved control of occupational lead exposures in recent decades such overt symptoms of lead toxicity are rare today in the United States. Occupational lead exposures allowable under the current OSHA lead standards will not produce these obvious neurologic clinical symptoms; however, lead exposures permissible under the OSHA standards may be harmful to the central nervous system.

As an example, workers with BLLs of 40 to 50 $\mu\text{g}/\text{dL}$ may experience fatigue, irritability, insomnia, headaches, and subtle evidence of mental and intellectual decline (CFR 1910.1025, 1998).

Studies also indicate a direct correlation between high blood lead levels and high blood pressure. Children and pregnant women are more susceptible to absorbing lead due to the developing state of the fetus and the increased nutritional demands placed on a pregnant woman's body. Blood-lead concentrations as low as 10 to 15 $\mu\text{g}/\text{dL}$ have been associated with neurological damage in children and increasing blood-lead levels have been highly correlated with decreased performance on standardized intelligence tests (i.e., lower I.Q. test scores).

Adverse health effects such as impaired hearing acuity and interference with vitamin D metabolism have also been observed at blood-lead levels of 10 to 15 $\mu\text{g}/\text{dL}$. Increased blood pressure, delayed reaction times, anemia, and kidney disease may become apparent at blood-lead concentrations between 20 and 40 $\mu\text{g}/\text{dL}$. Symptoms of very severe lead poisoning, such as kidney failure, abdominal pain, nausea and vomiting, and pronounced mental retardation can occur at blood-level concentrations as low as 60 $\mu\text{g}/\text{dL}$. At even higher concentrations, convulsions, coma, and death may result.

Extremely high concentrations of lead greater than 100 µg/dL of blood usually result in death (CFR 1910.1025, 1998).

The OSHA (Occupational, Safety and Health Standards) standards establish the minimum requirements for compliance when a lead exposure hazard exists. Specifically, the Code of Federal Regulation (CFR) 1910.1025 (1998) is the legal foundation for workplace compliance procedures and exposure levels for airborne lead particulates and fumes. When an employer becomes aware of a lead hazard in their employment facility, OSHA mandates certain compliance requirements to protect the employee and their family from an exposure to lead.

OSHA is very clear on what the minimum action level is and the controls that need to be put into place when a lead hazard has been brought to the employer's attention. The OSHA action level (AL) for an airborne concentration of lead is 30 micrograms per cubic meter of air. The permissible exposure level (PEL) is 50 micrograms of lead per cubic meter of air. These exposure levels establish the controls that an employer must put in place to protect an employee from exposure and dictate the amount of time an employee may perform a certain job function in a contaminated environment (CFR 1910.1025, 1998).

The OSHA regulations stipulate the rights of an employee from wrongful termination due to a job function being changed as a result of

a lead hazard and the employer's record keeping requirements. It is also the responsibility of the employer to educate employees and provide protective equipment such as respirators, clothing, and a place to change clothes, and shower facilities to prevent the transportation of lead to the home. These provisions must be made available to the employee at the employer's expense. OSHA establishes medical testing requirements to determine a baseline for blood lead levels and the removal of an employee from a job function that has placed that employee over the permissible blood lead levels (CFR 1910.1025, 1998).

CHAPTER III

RESEARCH METHODOLOGY

It was suspected that lead bromide dust was being released from the spark plug cleaning process into the shop areas and possibly exposing the mechanics to a lead hazard. It was first necessary to ascertain if lead was being released from the process and if so, determine the lead concentration levels in the various parts of the hangar.

If lead bromide dust was being introduced into the hangar environment and exposing employees, it would become necessary to create an engineering or a process control method to contain the lead bromide dust in a manner that would eliminate exposure hazards while requiring the least amount of additional steps or procedure changes. The optimum control method would provide the lowest level of interference with the duties of the mechanic and the efficiency of the process.

The first step was to conduct qualitative spot tests at the spark plug cleaning stations to determine if lead was being released. Due to the potentially ubiquitous spread of lead and its ability to spread unknowingly by airborne means, spot samples were also taken at areas where mechanics performed maintenance duties other than spark plug cleaning.

SPOT SAMPLE TESTING

It was necessary to determine if lead dust was present at the spark plug cleaning stations and whether it had spread to other locations throughout the maintenance facility. This determination was made by the use of a spot sample test.

The spot sample test is a qualitative positive or negative indicator for the presence of lead dust. The spot sample test yields a positive indication only when lead levels are present in quantities of greater than thirty micrograms per cubic centimeter. Thirty micrograms per cubic centimeter is a quantity not visible to the naked human eye.

The presence of lead is indicated by a change of the test media strip furnished in the test kit to a deep orange or a rose red color. The sample is valid when it is collected per the directions.

To identify the possible dispersal of the lead dust throughout the shop, sixteen spot samples were taken at locations throughout the maintenance facility using the Pace Environs, Inc., Lead Alert Professional Lead Test Kit. Spot samples were first taken from the areas where employees performed the spark plug cleaning process.

The location of the abrasive media blasting cabinet and the compressed air used by the mechanics to blow off the spark plugs after the final step suggested the possibility of lead being dispersed to other areas of the shop environment.

It was decided to test locations outside of the immediate spark plug cleaning area ranging around the entire shop. This spot testing could support the dispersal of lead to other areas other than the immediate spark plug cleaning areas.

Several areas frequented during the mechanic's duties throughout the shift were spot sampled for lead dust. The mechanics had placed a coffee maker in the shop environment to brew coffee. It was decided to test the area around the coffee maker because if lead dust was being dispersed throughout the shop then one possible avenue of an ingestion exposure could be from the coffee maker, which was uncontained and open to contamination. An open box of donuts is often found on the parts counter sill for the mechanics to enjoy during the day when they requisition parts. This could represent another avenue for oral ingestion of lead dust. Therefore the counter sill at the parts department was spot sampled for lead dust.

The keyboard at the technical publications desk was sampled as well as the work order bench and random toolbox worktops.

These areas were chosen because the employees often snacked and consumed beverages from open containers during the course of the workday. An employee could rest a snack or place a beverage on one of these work surfaces and then place it in their mouth resulting in the oral ingestion of lead dust.

The other areas that were spot sampled include the solvent tank on the far side of the shop opposite from the spark plug cleaning stations and battery charging areas were sampled to evaluate the airborne transmission of lead dust.

The office area was sampled to test if lead dust was being transported into that area by airborne means or from the clothing of the mechanics when they passed through the door exiting the work shift. The break room was sampled to test if any possible lead contamination was being taken into the separate facility on the clothing of the employee and then being consumed along with the meal of the employee.

Table 1 Spot Sample Locations

- #1. Test Equipment Verification
 - #2. Coffee Pot
 - #3. Battery Charging Area
 - #4. Parts Counter
 - #5. Parts Department Computer Keyboard
 - #6. Keyboard @ Tech Pubs Desk
 - #7. Workbench in Tool Room
 - #8. Work order Workbench
 - #9. Toolbox Worktop
 - #10. Spark Plug Vibrating Area
 - #11. Toolbox Worktop
 - #12. Toolbox Worktop
 - #13. Solvent Tank
 - #14. Random Floor Swipe From Center of Hangar
 - #15. Break room Table
 - #16. Keyboard in Maintenance Office
 - #17. Maintenance supervisors Office
-

See Figure 9 for the spot sample locations.

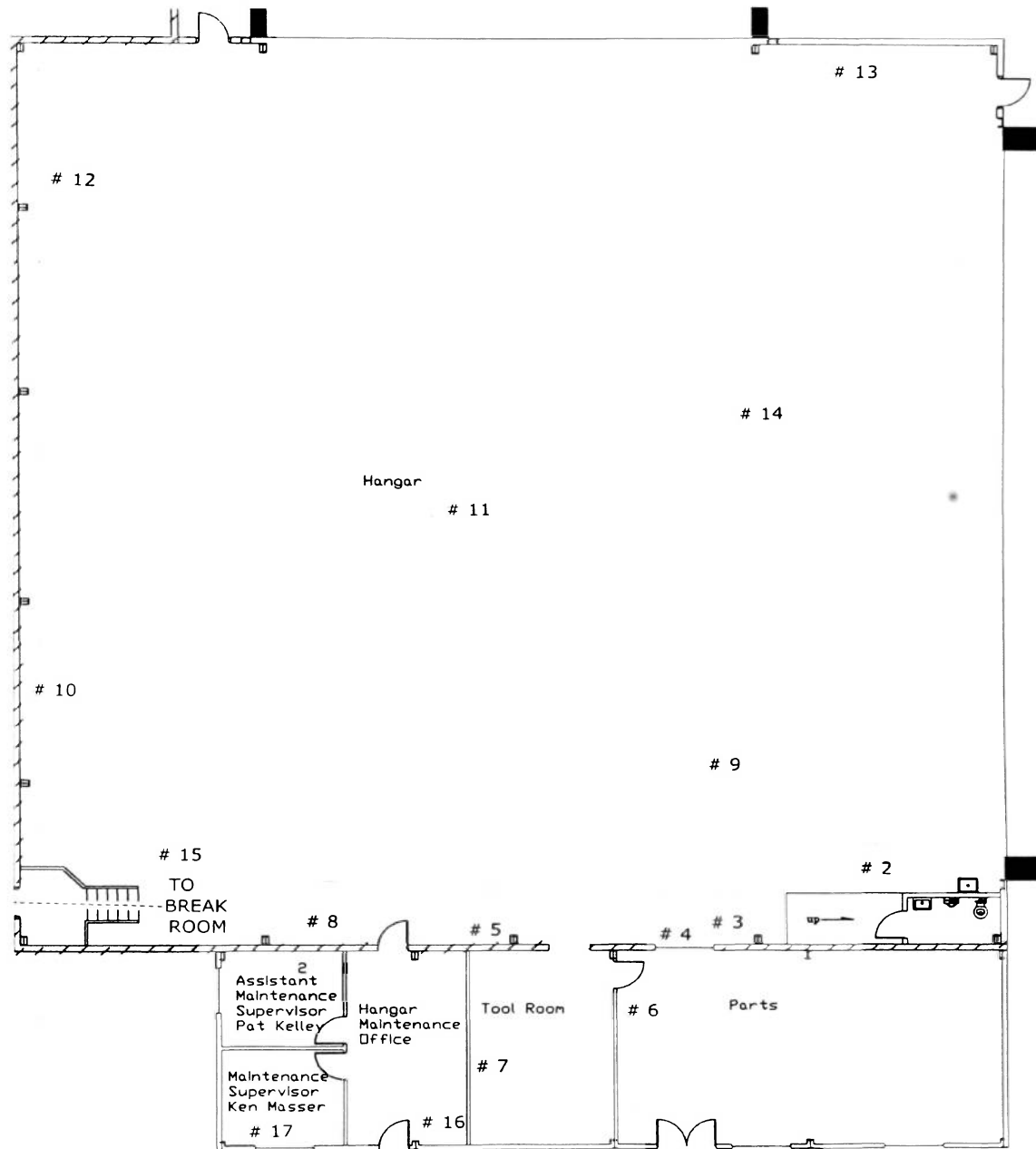


Figure 9. Spot Sample Locations

WIPE SAMPLE TESTING

Positive results were obtained from thirteen of the sixteen spot samples taken. This suggested further testing would be necessary to quantify the presence of lead dust in the maintenance facility. The next step after spot sampling was to conduct quantitative wipe samples to quantify the amount of lead dust present on the horizontal surfaces of the shop in the same proximate locations. The wipe samples were taken to determine how far the extent of the lead contamination was so that the appropriate cleanup operations could be performed.

Wipe samples were taken from some of the same horizontal locations as the spot samples throughout the maintenance facility. The original locations of the spot samples and the wipe samples were decided by the route the spark plugs followed during maintenance and the actions the mechanics took during the spark plug cleaning procedure. For example, stopping at the parts counter to get a donut or a cup of coffee from the coffee maker located near the parts room. Samples were taken from that route and expanded upon throughout the shop environment.

The wipe samples were taken in accordance with the NIOSH Method 9100, surface wipe sampling procedure (NIOSH Manual of Analytical Methods, May, 1996), see Appendix B. The samples were sent to Galson Laboratories, an American Industrial Hygiene Association (A.I.H.A.) accredited laboratory for analysis.

Due to budget constraints, only ten wipe samples were taken with two blank samples submitted as a control group for a total of twelve samples.

Table 2 Wipe Sample Locations

ER101402-01	Field Blank
ER101402-02	Field Blank
ER101402-03	Coffee Pot
ER101402-04	Battery Area
ER101402-05	Keyboard @ Tech Pubs
ER101402-06	Work order Workbench
ER101402-07	Spark Plug Cleaning Bench
ER101402-08	Workbench in Tool Room
ER101402-09	Parts Counter
ER101402-10	Desk in Maintenance Office
ER101402-11	Break Room Table
ER101402-12	Maintenance Supervisor's Desk

See Figure 10 for the wipe sample locations

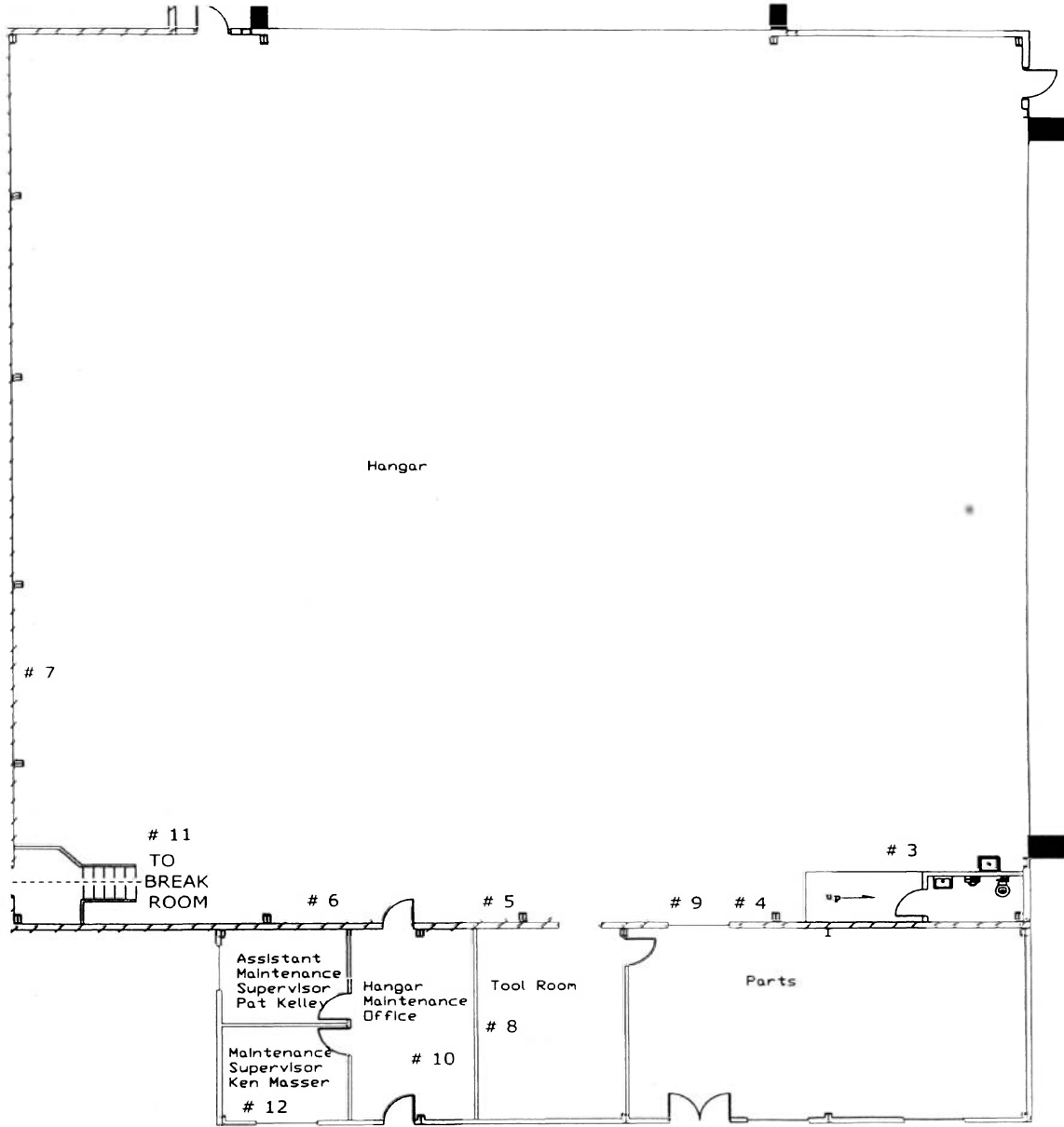


Figure 10. Wipe Sample Locations

AIR SAMPLING

Air sampling is the approved method used and accepted by OSHA for determining the exposure of a person to an airborne toxicological hazard. The air sampling procedure involves the use of a personal air pump that is flow calibrated and attached to a cassette cartridge containing the appropriate sampling media specified for the target hazard. The test subject wears the air-sampling pump for the period of time that the person may encounter an exposure that, in this case is a full eight-hour shift.

The last step for quantifying the presence of lead in the shop environment was to take actual air samples from employees to monitor their exposure to airborne lead. Employee personnel exposure samples to airborne lead were taken while mechanics were performing their duties during an eight-hour shift. The work shift was divided into three segments to more accurately quantify the exposure resulting from each segment. The three segments during which specific task related air samples were taken were: one air sample for general duties, one at the spark plug cleaning bench during the cleaning activity, and one at the abrasive media blasting station during the abrasive blasting process.

The air samples were taken over the mechanics full shift of eight hours. The air samples were taken using the SKC air check sampler calibrated to five liters per minute. The length of the sample periods varied depending on the length of time spent by the mechanic on each activity. Sampling was conducted on three mechanics to obtain an indication of exposure variability. The three mechanics volunteered to participate.

The air sample cassettes were exchanged when the mechanic began a different task during the spark plug cleaning process and after. The overall total of the three samples equaled one complete eight-hour shift sample of four hundred and eighty minutes.

The average period of time required for cleaning the spark plugs from one aircraft is approximately thirty minutes per group of spark plugs. The mechanic cleans an average of sixteen plugs, which is the equivalent of two aircraft per mechanic for each shift.

The air samples were sent to Galson Laboratories, an A.I.H.A. accredited laboratory for analysis. The results of the samples provided in Chapter IV are as follows.

CHAPTER IV RESULTS

This chapter presents the results obtained from the qualitative spot tests and quantitative wipe samples that were taken from horizontal surfaces in the shop environment and the air sampling results. The spot samples and wipe samples provided the necessary data to move forward with qualitative air sample testing for the employees performing the job of cleaning the spark plugs. The three sets of sampling results are presented in Tables 3, 4 and 5.

Spot Samples

The shop samples that tested positive in Table 3 represent a positive finding of lead dust in the shop environment. The break room samples and the office samples (As highlighted by asterisk in Table 3) were negative. This supports the likelihood that the lead dust is most likely not being transported to other areas that are operating with a separate or closed ventilation system that is not exposed to the spark plug cleaning operation. See Table 3 for the spot sample results. Lead Alert Professional Lead Test Kit results are not quantitative and are reported as positive and negative.

Table 3 Spot Sampling Results

Test Sample Location	Results
Spot #1, Test Equipment Verification	<u>Positive</u>
Spot #2, Coffee Pot	<u>Positive</u>
Spot #3, Battery Area	<u>Positive</u>
Spot #4, Parts Countertop at Windowsill	<u>Positive</u>
Spot #5, Keyboard at Tech Pubs	<u>Positive</u>
Spot #6, Keyboard Inside Parts Room	<u>Positive</u>
Spot #7, Tire Repair Bench	<u>Positive</u>
Spot #8, Work Order Bench	<u>Positive</u>
Spot #9, Work Bench Surface	<u>Positive</u>
Spot #10, Spark Plug Cleaning Bench	<u>Positive</u>
Spot #11, Random Toolbox in use on Shop Floor	<u>Positive</u>
Spot #12, Random Toolbox in Corner of Shop	<u>Positive</u>
Spot #13, Solvent Tank	<u>Positive</u>
Spot #14, Floor Sample	<u>Positive</u>
Spot #15, Break Room Table	* <u>Negative</u>
Spot #16, Keyboard in Office	* <u>Negative</u>
Spot #17, Ken Masser's (manager) Desk	* <u>Negative</u>

Wipe Sampling Results

The wipe sampling results returned from the Galson Laboratory revealed the presence of lead on all shop floor horizontal surfaces that were sampled. The level of quantitation for this particular test administered by Galson Laboratory was 0.38 mg per sample submitted.

The results obtained from the wipe sampling quantify the concentration levels of lead on various horizontal surfaces in the shop environment. The wipe samples that were taken from the office area and the break room support the possible transmission of lead throughout the maintenance environment by airborne means. Table 4 shows these test results.

Note: The prep blank and Control Blanks associated with these samples were outside control limits. Cross-contamination during prep from samples ER101402-07 is suspected; results for other samples may be biased high.

Table 4 Wipe Sampling Results

Sample#	Micrograms of lead per 10 cubic centimeter area	
ER101402-01	Control Blank	1.9
ER101402-02	Control Blank	1.61
ER101402-03		12.4
ER101402-04		61.5
ER101402-05		88.9
ER101402-06		16.1
ER101402-07		643000.0
ER101402-08		191.0
ER101402-09		41.3
ER101402-10		3.14
ER101402-11		2.06
ER101402-12		0.38

Air Sampling Results

Table 5 presents the air sampling results. These air sampling tests were conducted on three volunteer mechanics within E.R.A.U.'s F-5 Maintenance Facility. There were a total of 9 tests (3 task specific tests per 3 individuals) conducted by the researcher. The tests were divided into: 1) the general duty test; 2) the spark plug vibrating task; and 3) the abrasive media blasting cabinet task. Galson Laboratories provided the sample analysis.

Table 5 Air Sampling Results

**SPARK PLUG CLEANING LEAD EXPOSURES
FOR ONE AIRCRAFT, (ACTUAL)**

SAMPLE NUMBER	TIME IN MINUTES	$\mu\text{g}/\text{m}^3$	$\mu\text{g}\cdot\text{min}/\text{m}^3$	8 HOUR TWA
ER110602-01	445	53	23585	Micrograms of lead per cubic meter of air
ER110602-02	30	22	660	
ER110602-03	5	3400	17000	
TOTAL	480	3475	41245	85.93

ER110802-01	440	0.88	387.2	Micrograms of lead per cubic meter of air
ER110802-02	35	7.9	276.5	
ER110802-03	5	1300	6500	
TOTAL	480	1308.78	7163.7	14.92

ER111102-01	445	7.1	3159.5	Micrograms of lead per cubic meter of air
ER111102-02	30	2.5	75	
ER111102-03	5	1400	7000	
TOTAL	480	1409.6	10234.5	21.32

COMMENTS Data highlighted in red is above the OSHA permissible exposure level

- -01 suffixes denote general duty times and exposures.
- -02 suffixes denote the spark plug vibrator cleaning task times and exposures.
- -03 suffixes denote the abrasive media blasting cabinet task times and exposure
- TWA = Time Weighted Average

Example: An eight-hour time weighted average is calculated as follows:

Time in minutes	Concentration in $\mu\text{g}/\text{m}^3$	$\mu\text{g}\text{-min}/\text{m}^3$
Task 01 445 minutes	X 53 $\mu\text{g}/\text{m}^3$	= 23585
Task 02 30 minutes	X 22 $\mu\text{g}/\text{m}^3$	= 660
Task 03 5 minutes	X 3400 $\mu\text{g}/\text{m}^3$	= 17000
<hr/> Totals 480 minutes	<hr/> 3475 $\mu\text{g}/\text{m}^3$	<hr/> = 41245

Task Total Time = 480 minutes

Total Concentration of Pb per $\mu\text{g}\text{-min}/\text{m}^3 = 41245$

$(480) \times (3475) = 41245 (\mu\text{g} - \text{minutes})/\text{m}^3$ divided by the total task time of 480 = 85.93

85.93 $\mu\text{g}/\text{m}^3$ of Pb is the time weighted average exposure

During the course of an average work shift, it is very common for a mechanic to perform spark plug cleaning for more than one aircraft. The exposure data for a mechanic cleaning the spark plugs for two aircraft are extrapolated as follows.

Table 6 Estimated Time Weighted Average for Two Aircraft

FOR TWO AIRCRAFT, (ESTIMATED)				
SAMPLE NUMBER	TIME IN MINUTES	$\mu\text{g}/\text{m}^3$	$\mu\text{g}\text{-min}/\text{m}^3$	8 HOUR TWA
ER110602-01	410	53	21730	Micrograms of lead per cubic meter of air
ER110602-02	60	22	1320	
ER110602-03	10	3400	34000	
TOTAL	480	3475	57050	118.85

ER110802-01	400	0.88	352	Micrograms of lead per cubic meter of air
ER110802-02	70	7.9	553	
ER110802-03	10	1300	13000	
TOTAL	480	1308.78	13905	28.97

ER111102-01	410	7.1	2911	Micrograms of lead per cubic meter of air
ER111102-02	60	2.5	150	
ER111102-03	10	1400	14000	
TOTAL	480	1409.6	17061	35.54

COMMENTS Data highlighted in **red** is above the OSHA permissible exposure level

Example: An eight-hour time weighted average extrapolated for a mechanic performing the spark plug cleaning for two aircraft is calculated as follows:

	/Time in minutes		Concentration in $\mu\text{g}/\text{m}^3$	$\mu\text{g}\text{-min}/\text{m}^3$
Task 01	410 minutes	X	$53 \mu\text{g}/\text{m}^3$	= 21730
Task 02	60 minutes	X	$22 \mu\text{g}/\text{m}^3$	= 1320
Task 03	10 minutes	X	$3400 \mu\text{g}/\text{m}^3$	= 34000
<hr/>				
Totals	480 minutes		$3475 \mu\text{g}/\text{m}^3$	57050

Task Total Time = 480 minutes

Concentration in $\mu\text{g}/\text{m}^3 = 57050 \mu\text{g}\text{-min}/\text{m}^3$

$(57050) / (480)$ is $(\mu\text{g} - \text{minutes}) / \text{m}^3$ (57050) divided by the total task time of (480) = 118.85

118.85 $\mu\text{g}/\text{m}^3$ of Pb is the extrapolated time weighted average exposure for a mechanic cleaning the spark plugs for two aircraft during an eight hour shift.

CHAPTER V

DISCUSSION

The actual air sampling results showed one sample that was above both the PEL (permissible exposure level) and the AL (action level) for lead. Two samples were below the action level but they still warrant concern. Any exposure fluctuation due to the spark plug cleaning process as a result of uncontained lead bromide could easily cause an employee exposure over the permissible exposure limit. The compressed air used during the clean up of the shop can cause an additional lead exposure. The researcher observed that the employees were unaware of the fact that the matter being removed from the spark plugs was lead bromide. The employees were also unaware of the fact that the lead bromide was highly poisonous and that an amount of lead not visible to the human eye could cause an exposure. The matter that was removed from the spark plugs was considered to be dirt and was treated in the same fashion as a person would if they were to sweep up a pile of dust.

The prevailing management attitude was less than encouraging. The management views any change in the spark plug cleaning procedure as an attempt to alter productivity from an established procedure and therefore was unwilling to explore alternative methods of exposure mitigation.

The uncontained lead bromide dust being emitted from the spark plug cleaning process is being inhaled by the employees that perform the spark plug cleaning process and the clean up of the surrounding areas associated with the process. The researcher observed that the employees were performing the spark plug cleaning tasks without the use of personal protective equipment such as respirators or aprons.

The employer provides daily work clothing for the mechanics in the form of jeans and polo style shirts. When asked about whether the mechanics change their clothing at work or at home they responded that they changed their clothing at home. It is very possible that the lack of proper changing facilities and shower provisions could introduce a lead exposure to the family members of the mechanic by transporting the lead dust home on the clothing. If the mechanic has young children they would be particularly at risk of a lead exposure.

The wipe samples taken from around the shop revealed that lead was being disbursed to all areas of the shop.

In order to properly prevent the future exposure of mechanics from the residual lead dust residing in the shop, it would be necessary to perform a complete cleaning of the maintenance facility. The contamination of the building from lead necessitates the cleaning of

the shop environment to eliminate the risk of a future lead exposure by a person inadvertently disturbing the dust and inhaling it or ingesting it.

The spark plug cleaning operation should be removed from the shop environment completely and the appropriate environmental controls should be implemented to eliminate exposure risks. The environmental controls would contain the lead bromide dust as it is removed from the spark plug during the vibrating task through the incorporation of control devices such as the local exhaust ventilation system described in the following chapter. The installation of a HEPA vacuum cleaner for the secondary abrasive blasting stage of the spark plugs would further control the lead dust as it is removed from the spark plugs. Developing a controlled quantity of cleaned and gapped spark plugs that could be exchanged for used ones is a step that could reduce or eliminate exposures during the cleaning process. The following guidelines set forth by NIOSH and OSHA regulations (29CFR 1910.1025) apply to all forms of occupational lead exposure, see Appendix C. They specify procedures that employers must implement when a lead hazard is present in the work place. The air sampling results revealed exposures above the action level on two of the mechanics and exceeded the permissible exposure level on one of the mechanics.

The action level for airborne lead exposure is thirty micrograms of lead $\mu\text{g}/\text{m}^3$ of air in an eight Hour shift. The permissible exposure level is fifty micrograms of lead $\mu\text{g}/\text{m}^3$ of air of in an eight-hour shift.

The employer must determine who may be exposed to lead in the work place. Employee exposure is defined as that which would occur if the employee were not using a respirator. The employer must conduct monitoring of workplace and of the employee if the lead levels are above the action level of thirty micrograms per cubic meter of air. If lead levels are above the action level of $30 \mu\text{g}/\text{m}^3$ and below the permissible exposure level testing must be repeated every six months. If lead levels are above the permissible exposure level of fifty micrograms $\mu\text{g}/\text{m}^3$ per cubic meter of air then testing must be repeated every three months. No employee may work for more than thirty days per year at exposure levels exceeding the permissible exposure level.

The regulations specify the employer's responsibilities for safe work place practices. If airborne lead exposure is above the permissible exposure level, the employer must establish a specific work area for performing lead related tasks. The employer must provide appropriate work clothing and equipment to prevent contamination for all employees that may become exposed to

unhealthy levels of lead through skin or eye irritation from lead compounds. The employer must also provide the following:

- A respirator
- Personal protective clothing
- Clothes changing area (s)
- Biological monitoring consisting of blood level analysis
- Safety instructions, signage, and training for employees
- A safe zone to eat

Exposures greater than the action level of thirty micrograms per cubic meter $\mu\text{g}/\text{m}^3$ of air require a medical exam and biological monitoring of the employee (blood tests).

Air samples are to be taken for a full-eight hour shift or representative thereof. Until such sampling is performed, the employer must treat the employee (s) as if they have been exposed above the permissible exposure level of fifty $\mu\text{g}/\text{m}^3$ micrograms of lead per cubic meter of air as an eight-hour time weighted average. The employer must implement a written compliance program prior to the commencement of lead related activities above the PEL. The plan must describe operations where lead may be emitted and the type of equipment being used. The plan must detail which activities are performed where an employee may be exposed to lead.

CHAPTER VI

CONCLUSIONS

The detection of lead bromide at the Embry-Riddle Prescott Arizona maintenance facility above permissible OSHA levels requires the employer to implement controls that comply with the general industry lead standard of OSHA 29 CFR 1910.1025 to safeguard employees from future exposure. The areas of the maintenance facility that are contaminated with lead must be cleaned in an appropriate manner and the necessary employee personal protective equipment must be made available to the employee. Employees must be educated about the work place hazards that they face regarding lead exposure.

Appropriate clothes changing areas and shower facilities need to be made available for the employees and medical monitoring of all of the people involved with the handling of lead needs to be instituted. The spark plug cleaning process currently lacks controls to prevent lead exposures.

CHAPTER VII

RECOMMENDATIONS

Three possible solutions to mitigate and control the lead exposure from the spark plug vibrator will be suggested for evaluation.

The first control method that will be examined is the use of a local exhaust ventilation (LEV) system to contain the lead bromide as it is removed from the spark plug electrode. The purpose of containment is to control the release of the lead bromide that is removed from the spark plug during the cleaning process to prevent exposing the person performing the cleaning task to lead dust. This containment method requires the addition of an annular air inlet fitted to the Champion spark plug vibrator cleaner combined with a HEPA vacuum system to capture the lead bromide particulate as it is agitated free from the spark plug electrode area. The LEV is designed using the guidelines of the ACGIH Industrial Ventilation manual, 23rd Edition. The design information is provided in Appendix D. The LEV system is described below. It is to be attached to the Champion Spark Plug Cleaner. The required capture velocity of a flow volume of 32.6 cubic feet per minute at the entrance to the LEV is determined as follows.

The aircraft spark plug is one inch in diameter and the orifice of the control device is two inches in diameter. This dimension provides a one-half inch donut shaped opening around the spark plug when it is inserted into the opening.

The Design of the Local Exhaust Ventilation Control Device Encloses the Firing End of the Spark Plug



Figure 11 Local Exhaust Ventilation Control Device



Figure 12 Local Exhaust Ventilation Control Device With User
Demonstrating Spark Plug Cleaning

The second recommendation is to use iridium spark plugs in place of the massive electrode spark plugs. This approach eliminates the lead exposure problem and has cost advantages described in Appendix E.

The third method of virtually eliminating lead exposure to the mechanic from the spark plug cleaning process would be to establish a suitable supply of the required spark plugs in the parts storage room and exchange them out to the mechanic at the fifty hour maintenance cycle. The mechanic would remove the spark plugs from the aircraft and exchange them with the parts department for a fresh batch of cleaned and reconditioned spark plugs. The parts department could then place the fouled spark plugs in a hazardous collection containment unit or area to be retained until enough spark plugs were collected for cleaning. A trained and qualified person with the proper personal protective equipment could perform the cleaning task at a controlled location. A large volume of the spark plugs could be cleaned, gapped, preserved and returned to the parts room to be issued as required to the mechanics.

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APPENDIXES

APPENDIX A

Lead Bromide

Use:

Molecular formula: PbBr_2

CAS No: 10031-22-8

EC No: 233-084-4

EU No: 082-001-00-6

Physical data

Appearance: white powder

Melting point: 373 C

Boiling point: 916 C

Vapour density:

Vapour pressure:

Density (g cm^{-3}): 6.7

Flash point:

Explosion limits:

Autoignition temperature:

Water solubility:

Stability Stable.

Toxicology

Toxic if swallowed, inhaled or absorbed through the skin. May cause reproductive damage. Danger of cumulative effects. A possible, human carcinogen. Typical PEL/TWA 0.1 mg/m³ as Pb.

APPENDIX B

LEAD in Surface Wipe Samples

9100

Pb MW: 207.19 CAS: 7439-92-1 RTECS: OF7525000

METHO D: 9100, Issue 2 EVALUATION: NOT APPLICABLE Issue 1: 15

August 1994

Issue 2: 15 May 1996

PURPOSE: Determination of surface contamination by lead and its compounds.

LIMIT OF DETECTION: 2 μg Pb per sample (0.02 $\mu\text{g}/\text{cm}^2$ for 100-cm² area) by flame AAS [1] or ICP [2]; 0.1 μg Pb per sample (0.001 $\mu\text{g}/\text{cm}^2$ for 100-cm² area) by graphite furnace AAS [3,4].

FIELD EQUIPMENT:

1. Resealable hard-walled sample containers, e.g., 50-m L plastic centrifuge tubes [5].
2. Wipes: Disposable towlettes moistened with a wetting agent.

NOTE 1: Wipes selected for use should contain insignificant (<5 μg Pb) background lead levels [4,5]. Wipes should be individually wrapped and pre-moistened; for example, Wash'n Dri™ hand wipes (or equivalent).

NOTE 2: Whatman filters should NOT be used for wipe sampling, because they are not sufficiently durable.

3. Powderless plastic gloves, disposable
4. Template, plastic or steel; 10 cm x 10 cm or other standard size.
5. Tape Measure.
6. Masking Tape.

SAMPLING:

1. Don a clean pair of gloves.
2. Place the template over the area to be sampled, and secure the outside edges with masking tape. If the area to be sampled is in a confined area and a template cannot be used, measure the sampling area with the tape measure, and delineate the area to be sampled with masking tape.
3. Remove a wipe from its package, and unfold it.
4. Re-fold the wipe into fourths, and wipe the surface to be sampled with firm pressure. Use an overlapping "S" pattern to cover the entire surface area with horizontal strokes.
5. Fold the exposed side of the wipe in, and wipe the same area using vertical "S"-strokes.
6. Fold the wipe once more to reveal an unexposed surface, and wipe the surface a third time as described in step 4.

7. Fold the wipe, exposed side in, and place it into a clean hard-walled sample container (e.g., 50-mL centrifuge tube). Seal securely, and clearly label the sample container.

NOTE: Compositing of wipe samples is not recommended, because (a) they cause sample preparation and analytical difficulties, and (b) site-specific analytical information is lost.

8. Clean the template in preparation for the next wipe sample.

9. Discard gloves.

10. Field blanks: 5% of samples, at least two per sample set. Remove unexposed wipes from their packaging and place into sample containers.

SAMPLE PREPARATION:

Use the procedure of NIOSH Method 7105 or equivalent [3,6], including final sample

LEAD in Surface Wipe Samples: METHOD 9100, Issue 2, dated 15 May 1996 - Page 2 of 2 NIOSH Manual of Analytical Methods (NMAM),

Fourth Edition, 5/15/96

dilution to 10 mL.

NOTE: Additional portions of nitric acid may be needed for complete digestion of the wipe sample. Include appropriate media and reagent blanks.

MEASUREMENT:

Depending on detection limit required, use the procedures of NIOSH methods 7082

(Lead by flame AAS) [1], 7300 (Elements by ICP) [2], or 7105 (Lead by graphite furnace AAS) [3], or equivalent methods [6,7].

REFERENCES:

[1] NIOSH [1994]. Lead by FAAS: Method 7082. In: Eller PM, Cassinelli ME, Eds., NIOSH Manual of analytical methods, 4th ed.^o Cincinnati, OH: U.S. Department of Health and Human Services, DHHS (NIOSH) Publication No. 94-113.

[2] *Ibid.* Elements by ICP: Method 7300.

[3] *Ibid.* Lead by GFAAS: Method 7105.

[4] Millson M, Eller PM, Ashley K [1994]. Evaluation of wipe sampling materials for lead in surface dust. *Am Ind Hyg Assoc J* 55: 339-342.

[5] ASTM [1994]. Emergency standard practice for field collection of settled dust samples using wipe sampling methods for lead determination by atomic spectrometry techniques: ASTM ES 30. In: ASTM standards on lead-based paint abatement in buildings. Philadelphia, PA: American Society for Testing and Materials.

[6] *Ibid.* Emergency standard practice for hot plate digestion of dust wipe samples for determination of lead by atomic spectrometry: ASTM ES 36.

[7] *Ibid.* Standard test method for analysis of digested samples for lead by inductively coupled plasma atomic emission spectrometry (ICP-AES), flame atomic absorption (FAAS), or graphite furnace atomic absorption (GFAAS) techniques: ASTM E 1613.

METHOD WRITTEN BY:

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[Title 29, Volume 6, Parts 1910.1000 to end]

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APPENDIX C

TITLE 29--LABOR

CHAPTER XVII--OCCUPATIONAL SAFETY AND HEALTH

ADMINISTRATION, DEPARTMENT OF LABOR (Continued)

PART 1910--OCCUPATIONAL SAFETY AND HEALTH STANDARDS

(Continued)--Table of Contents

Subpart Z--Toxic and Hazardous Substances

Sec. 1910.1025 Lead.

D. Permissible Exposure: The Permissible Exposure Limit (PEL) set by the standard is 50 micrograms of lead per cubic meter of air (50 $\mu\text{g}/\text{m}^3$), averaged over an 8-hour workday.

E. Action Level: The standard establishes an action level of 30 micrograms per cubic meter of air (30 $\mu\text{g}/\text{m}^3$), time weighted average, based on an 8-hour work-day. The action level initiates several requirements of the standard, such as exposure monitoring, medical surveillance, and training and education.

ii. health hazard data

A. Ways in which lead enters your body. When absorbed into your body in certain doses lead is a toxic substance. The object of the lead standard is to prevent absorption of harmful quantities of lead.

The standard is intended to protect you not only from the immediate toxic effects of lead, but also from the serious toxic effects that may not become apparent until years of exposure have passed.

Lead can be absorbed into your body by inhalation (breathing) and ingestion (eating). Lead (except for certain organic lead compounds not covered by the standard, such as tetraethyl lead) is not absorbed through your skin. You can also absorb lead through your digestive system if lead gets into your mouth and is swallowed. A significant portion of the lead that you inhale or ingest gets into your blood stream. Once in your blood stream, lead is circulated throughout your body and stored in various organs and body tissues. Some of this lead is quickly filtered out of your body and excreted, but some remains in the blood and other tissues. As exposure to lead continues, the amount stored in your body will increase if you are absorbing more lead than your body is excreting. Even though you may not be aware of any immediate symptoms of disease, this lead stored in your tissues can be slowly causing irreversible damage, first to individual cells, then to your organs and whole body systems.

B. Effects of overexposure to lead--(1) Short term (acute) overexposure. Lead is a potent, systemic poison that serves no known useful function once absorbed by your body. Taken in large enough doses, lead can kill you in a matter of days.

APPENDIX D

The area of the opening is determined by calculating the area of the outer circle and subtracting the area of the inner circle and then dividing by 144

Outer circle $(\pi) \times (r)^{(2)}$ - Inner circle $(\pi) \times (r)^{(2)}$

$$\begin{aligned} & (3.1415) \times (1.0)^{(2)} = 3.1415 \\ & \underline{- (3.1415) \times (0.5)^{(2)} = 0.7853} \\ & \qquad \qquad \qquad 2.3562 \end{aligned}$$

2.3562 is then divided by 12^2 or 144

Thus, $2.3562/144 = .0163 \text{ ft}^2$ area of the annular air inlet.

The resulting area of the donut is $.0163 \text{ ft}^2$.

The required capture velocity is listed in chapter 3-6 of the Industrial Ventilation Guide, 23rd edition. It lists a maximum capture velocity for contaminants of high toxicity at 2000 ft/min. The volume of air required for the annular air inlet is determined by the equation of quantity or $Q = (\text{area}) \times (\text{velocity})$

Therefore; $Q = (.0163) \times (2000 \text{ ft/min})$

$$Q = 32.6 \text{ ft}^3/\text{min}$$

APPENDIX E

Iridium spark plugs cost an average of \$55.00 a piece. The Lycoming four-cylinder engine requires eight spark plugs.

Thus $8 \times \$55.00 = \440.00

This would be a cost of \$440.00 for a set of eight iridium spark plugs for each engine. The iridium spark plugs have a longer service life that is essentially three times longer than that of the life of the massive electrode spark plug (750 hours compared to 250 hours of service life). Iridium spark plugs require fewer if any cleaning intervals due to the catalytic nature of the iridium. The main drawback of iridium fine wire spark plugs is the high initial purchase cost of the iridium spark plug.

The massive electrode spark plugs average cost per spark plug is \$22.00 resulting in a cost of \$176.00 per engine. The massive electrode spark plug usually requires servicing at fifty-hour intervals for cleaning. The massive electrode spark plugs usually have a service life of 250 hours or less at which point they are replaced. If the Iridium spark plugs have a service life of 750 hours and the massive electrode spark plugs have a service life of 250 hours then a simple cost benefit analysis is easy to perform.

The massive electrode spark plug overall cost is as follows.

\$22.00 = cost per individual spark plug.

8 = quantity of spark plugs per engine.

\$176.00 = initial purchase price for massive electrode spark plugs.

\$75.00 = Estimated shop overhead per hour.

250 = Life expectancy in hours of massive electrode spark plugs.

50 = period in hours for cleaning of massive electrode spark plugs.

1 = period in hours to perform cleaning of spark plugs.

$750/250$ = ratio in hours of product life cycle between fine wire spark plugs and massive spark plugs.

Therefore $750/250 = 3$

Thus follows the equation:

$$\underline{250/50 = (5) \times (\$75.00) = (\$375.00 + \$176.00) \times (3) = \$1653.00}$$

The iridium fine wire spark plug overall cost is as follows.

\$55.00 = cost per individual spark plug.

8 = quantity of spark plugs per engine.

\$440.00 = initial purchase price for massive electrode spark plugs.

\$75.00 = Estimated shop overhead per hour.

750 = Life expectancy in hours of massive electrode spark plugs.

>50 or not at all = period in hours for cleaning of massive electrode spark plugs.

0,1 or 2 = period in hours to perform cleaning of spark plugs.

$750/>100 = (7.5) \times (\$75.00) = (\$562.5 + \$440.00) \times (0) = \$1002.50$

$250/50 = (5) \times (\$75.00) = (\$375.00 + \$176.00) \times (3) = \1653.00

$750/>100 = (7.5) \times (\$75.00) = (\$562.5 + \$440.00) \times (0) = \$1002.50$

\$650.50

A difference of \$650.50 is realized over a 750 hour period of operation.

A potential savings for a 750 hour operating period could yield a reduction in expense of \$650.50