Guidelines for the Use of Personal Protective Equipment (PPE) in Thermal Spraying

Prepared by the ASM-TSS Safety Committee

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Comments, criticisms, and suggestions are invited, and should be forwarded to the Thermal Spray Society of ASM International®.

CONTENTS

1 SCOPE AND OVERVIEW

It is the belief of the Thermal Spray Society Safety Committee that every person is entitled to work in a safe and healthful environment. People are the most important assets in the Thermal Spray Community and their health and safety is the community's greatest responsibility.

This document "*Guidelines for the Use of Personal Protective Equipment in Thermal Spraying*" is intended to provide information consistent with the United States Occupational Safety and Health Administration's (OSHA) Personal Protective Equipment Standard (29 CFR 1910.132-138). All information is presented in the context of Thermal Spraying.

Personal Protective Equipment (PPE) is intended to protect individuals from the risk of injury by creating a barrier against workplace hazards. Personal protective equipment is not a substitute for good engineering controls, administrative controls, or good work practices. Instead, it should be used in conjunction with these controls to ensure the safety and health of workers.

The thermal spray enclosure (spray booth) is the most important safety device (PPE not withstanding) used in thermal spray processing. The use of a spray enclosure is always preferable to the use of PPE. The primary role of a thermal spray enclosure is to contain and/or control various hazards associated with thermal spray processing of materials. Because the spray operations are conducted within its confines, all of the energy sources (gas, electricity, and water), the feedstock materials, and all of the process effluents (heat, dust, fumes, sound, and ultraviolet light) are present and controlled.

Engineering controls, administrative controls, and good work practices are always preferred instead of PPE as methods to protect workers against workplace hazards. Nevertheless, many situations exist in which a fully enclosed spray booth cannot be used or where an operator must enter a spray booth while the spray device is operating. Personal protective equipment should be used when it has been determined that its use will lessen the likelihood of occupational injury and/or illness and when other protection methods are not available. These situations demand the use of PPE.

This document provides guidelines for establishing PPE programs, assessing hazards associated with thermal spray operations, and training workers about PPE, as well as guidelines for selecting, using, and maintaining PPE. This document also provides an overview of eye, face, head, hand, foot, hearing, fall, and respiratory protection. Respiratory and hearing protection should be used in conjunction with industrial hygiene monitoring.

These guidelines are written within the context of the prevailing internationally accepted practices and standards, as well as United States laws and regulations. They are intended to have worldwide application. It is incumbent upon each individual, company, or institution referencing these guidelines, to ensure compliance with all relevant local country/community laws, rules and regulations, and to apply generally accepted, good engineering practice to the selection, use, and maintenance of personal protective equipment.

Thermal Spray activities are complex and involve many different materials and situations. Because of the diverse nature of thermal spray process requirements, this document alone cannot provide all the information needed for PPE selection, use, and maintenance. Suppliers of PPE and health and safety professionals with expertise in specific aspects of industrial hygiene should be consulted to ensure the safety and health of workers.

This guideline is intended for use in conjunction with the other reference publications, local publications, and applicable standards. An extensive, but not comprehensive, list of these is included in Section 2*, RELATED STANDARDS AND DOCUMENTS*

2 RELATED STANDARDS AND DOCUMENTS

Where standards and other documents are referenced in this publication, they refer to the latest edition.

U.S. Standards		
Publication	**Title**	**Available from:**
ASTM Publications: ASTM F2413-11:	Standard Specification for Performance Requirements for Protective (Safety) Toe Cap Footwear.	American Society for Testing and Materials 100 Bar Harbor Drive West Conshohocken, PA 19428-2959 www.astm.org
ANSI Publications: ANSI Z87.1-2010 ANSI Z89.1-1986 ANSI 105-2011 ANSI Z359.1	Standard for Occupational and Educational Eye and Face Protection Devices. Standard for Industrial Head Protection Standard for Hand Protection Selection Criteria Safety Requirements for personal Fall Arrest Systems	American National Standards Institute 1430 Broadway New York, NY 10018 www.ansi.org
ASM-TSS Publications:	Thermal Spray Booth Design Guidelines Safety Guidelines for Performing Risk Assessments	ASM International® 9639 Kinsman Road Materials Park, OH 44073-0002 www.asminternational.org
AWS Publication	AWS C2.16 Guide for Thermal Spray Operator Qualification	American Welding Society 550 NW. LeJeune Road Miami, Florida 33126 1-800-443-9353 e-mail: info@aws.org

U.S. Standards		
Publication	**Title**	**Available from:**
OSHA Publications	Occupational Safety and Health Act of 1970 29 CFR 1910 Subparts A – Z	Occupational Safety and Health Administration 1-800-321-OSHA for nearest location www.osha.gov
1910.132	General Requirements	
1910.133	Eye and Face Protection	
1910.134	Respiratory Protection	
1910.135	Head Protection	
1910.136	Foot Protection	
1910.137	Electrical Protection	
1910.138	Hand Protection	
1910.335	Electrical: Safeguards for Personnel Protection	
1910.95	Hearing Protection	
1910 Subpart D	Walking-Working Surfaces	
1926 Subpart M	Fall Protection (Note: this is part of CFR 1926 for Construction)	

European Directives		
Publication	**Title/Contents**	**Available from:**
Council Directive 89/656/EEC -	**Use of personal protective equipment** of 30 November 1989 on the minimum health and safety requirements for the use by workers of personal protective equipment at the workplace (third individual directive within the meaning of Article 16 (1) of Directive 89/391/EEC).	All of this information, and more, can be found at: http://osha.europa.eu/legislation/
Council Directive 89/686/EEC -	**Personal protective equipment** of 21 December 1989 on the approximation of the laws of the Member States relating to personal protective equipment.	
Council Directive 92/58/EEC -	**Safety and/or health signs** of 24 June 1992 on the minimum requirements for the provision of safety and/or health signs at work (ninth individual Directive within the meaning of Article 16 (1) of Directive 89/391/EEC).	
Council Directive 90/269/EEC (EU) -	**Manual handling of loads** of 29 May 1990 on the minimum health and safety requirements for the manual handling of loads where there is a risk particularly of back injury to workers (fourth individual Directive within the meaning of Article 16 (1) of Directive 89/391/EEC), Official Journal n° L 156, 21.06.1990, p. 9	
Council Directive 98/24/EC	of 7 April 1998 on the protection of the health and safety of workers from the risks related to chemical agents at work (fourteenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC)	

European Directives		
Publication	**Title/Contents**	**Available from:**
Council Directive 89/655/EEC	of 30 November 1989 concerning the minimum safety and health requirements for the use of work equipment by workers at work (second individual Directive within the meaning of Article 16 (1) of Directive 89/391/EEC)	
Council Directive 2003/10/EC	on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise)	

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3 TERMINOLOGY / DEFINITIONS

ACGIH – American Council of Industrial Hygienists.

Administrative Controls – Reducing the risk of injury through management of the processes and workforce.

Action level – under OSHA regulations it is a concentration of a specific substance or hazard calculated as an eight (8)-hour time-weighted average, which initiates certain required activities such as exposure monitoring and medical surveillance. Typically, the AL is one-half the PEL level.

ANSI – An abbreviation for American National Standards Institute.

ASTM – An abbreviation for American Society for Testing and Materials.

AWS – An abbreviation for the American Welding Society.

Approved – Acceptable to the authority having jurisdiction.

CGA – An abbreviation for the Compressed Gas Association.

Detonation Gun – A thermal spray device that employs rapid detonation of an oxygen-fuel mixture to heat and carry coating powders to the surface of a part in order to apply a coating that enhances the part's surface performance properties.

Decibel (dB) – A numerical expression of the relative loudness, or intensity, of a sound. The difference in decibels between two sounds is ten times the logarithm of the ratio of their power levels. The "A" suffix when used with dB (dBA) signifies a non-linear averaging of noise levels across ten octave bands to compensate for human ear sensitivity to sound at various frequencies.

Dry Ice (CO_2 Snow) – the solid state of carbon dioxide. Usually forms when a sudden pressure release of CO_2 occurs such as spraying.

Effluent – A term used to encompass all the gases, particulate, fumes, etc. emitted from a thermal spray gun or torch.

Enclosure – The cabinet or housing of apparatus or the fence or wall surrounding an installation to prevent personnel from personal injury hazards or to protect the equipment from physical damage.

Engineering Controls – Reducing the risk or potential for injury by incorporating safety systems, features, interlocks, etc. into the design of machines, tools, layouts and processes.

EPA – abbreviation used for the Environmental Protection Agency (USA).

Equipment - A general term including materials, fittings, devices, appliances, fixtures, apparatus and the like used as a part of, or in connection with, a thermal spray installation.

Ergonomics – The process or science of adapting workstations, tools, equipment and work techniques to be compatible with human anatomy and physiology so as to reduce the risk of injury due to occupational activity or stresses.

Fuel Gas – Any combustible gas, including hydrogen, propane, propylene, acetylene, MAPP, etc. used in a thermal spray process.

Fumes – Particulate matter consisting of particles generated by the condensation of gases created by evaporation of melted substances**.**

Frequency – The number of cycles-per-second of a device, signal, or parameter. Generally expressed in Hertz (Hz).

HEPA – An abbreviation used for High Efficiency Particulate Air. In reference to air filters, it specifies that 99.97% of particles larger that 0.3 micron will be removed from the air stream.

HVOF – High Velocity Oxygen Fuel. This type of high velocity coating process uses a liquid or gaseous fuel combusted with oxygen to heat and carry coating material to the surface of a part in order to enhance the part's surface performance properties.

HVAF – High Velocity Air Fuel. This type of high velocity coating process uses a gaseous fuel with air to heat and carry coating material to the surface of a part to enhance its surface features.

LPPS – Low Pressure Plasma Spray. See preferred term Vacuum Plasma Spray Deposition.

Lock-out/Tag-out – The process of locking and tagging any energy source (typically a valve or electrical shutoff) to isolate sources of energy during maintenance/repair and prevent inadvertent operation **–** or release of energy or hazardous material.

MSDS (or SDS) – An abbreviation used for Material Safety Data Sheet, also known as Safety Data Sheet.

NFPA (National Fire Protection Association) – A U.S. based organization providing advisory standards offered for use in law and for regulatory purposes in the interest of life and property protection.

NIOSH – National Institute for Safety and Health

Noise - Unwanted sound which may be hazardous to health, interferes with communications, or is disturbing.

OSHA – Occupational Safety and Health Administration (USA).

Permissible Exposure Limit (PEL) – is the maximum amount or concentration of a chemical that a worker may be exposed to under OSHA regulations.

Personal Fall Arrest System – A system used to arrest an employee in a fall from a working level. It consists of an anchorage, connectors, a body belt or body harness and may include a lanyard, deceleration device, lifeline, or suitable combinations of these. As of January 1, 1998 the use of a body belt for fall arrest is prohibited.

Process Equipment – The mechanical and/or electrical devices and associated control systems that are used to produce coatings or produce surface enhancements, and whose operation directly affects the chemistry, or the physical properties, of the final product. Typically, this includes gas consoles, regulator panels, hose bundles, powder feeders, gases and gas supplies, and the thermal spray gun or torch.

Qualified Person – A person, who by reason of experience or instruction has demonstrated familiarity with the operation to be performed and the hazards involved.

REL (Recommended Exposure Limit) – An 8 or 10-hour time-weighted average (TWA) or ceiling (C) exposure concentration recommended by NIOSH that is based on an evaluation of health effects data.

Sound – A vibrational disturbance, exciting hearing mechanisms, transmitted in a predictable manner determined by the medium through which it propagates.

Sound Pressure – Fluctuations in air pressure caused by the presence of sound waves.

Sound Pressure Level - The intensity of a sound, expressed in decibels (dB).

Spray Booth – An enclosure for thermal spray processes that is specifically designed to mitigate process hazards. A spray booth is NOT designed for human occupancy during routine spray operations; however, it is routinely occupied for maintenance and process setup.

Spray (Coating) Box – A spray (coating) box is an enclosure for thermal spray processes that is specifically designed to mitigate process hazards. These boxes are NOT designed for human occupancy during routine spray operations, process setup and routine maintenance.

Spray Enclosure – A term used in this document whenever a statement is equally applicable to either a spray booth or a spray (coating) box.

Threshold Limit Value (TLV) – are guidelines prepared by the *American Conference of Governmental Industrial Hygienists, Inc (ACGIH)* to assist in making decisions regarding safe levels of exposure to various hazards found in the workplace. A TLV reflects the level of exposure that the typical worker can experience without an unreasonable risk of disease or injury.

Vacuum Plasma Deposition (VPD) – A thermal spraying process variation utilizing a plasma gun confined to a solid enclosure. The enclosure is evacuated and the spraying performed under low pressure, also known as Vacuum Plasma Spray (VPS), Low Pressure Plasma Spray (LPPS®).

Ventilation System – A complete air handling and filtration system for a thermal spray booth from the intake of air into the process to the exhaust of the air back into the atmosphere. In this document, the spray booth is considered as part of the exhaust system in regard to air flow.

4. PPE PROGRAM: TYPICAL RESPONSIBILITIES OF EMPLOYERS, SUPERVISORS, AND WORKERS

This section sets forth minimum personal protective equipment (PPE) requirements. It also provides an overview of PPE program responsibilities for employers, supervisors, and employees. It includes workplace assessments, supplying PPE, care, maintenance, and training.

4.1 Employers

The ultimate responsibility for implementing a PPE program resides with the company/employer. It is recommended that every company/employer performing thermal spray operations establish a formal PPE program. This program should:

- Document and explain the companies PPE policies and the PPE procedures to be followed by supervisors and employees.
- Identify a person as the PPE program leader
- Explain the methods for performing hazard assessments
- Explain the requirements for documenting hazard assessments, training, and PPE records

4.2 Supervisors

Supervisors typically have the primary responsibility for implementation of PPE Programs in their work area. This involves:

- Conducting workplace hazard assessments to determine the presence of hazards which necessitate the use of PPE.
- Providing appropriate PPE and making it available to all workers.
- Ensuring workers are trained on the proper use, care, and cleaning of PPE.
- Maintaining records on PPE assignments and training.
- Supervising workers to ensure that the PPE Program elements are followed and that employees properly use and care for their PPE.
- Posting instructional signs relative to the requirement for PPE (e.g., “All persons entering this area must wear safety glasses.”)
- Seeking assistance from industrial hygienists to evaluate hazards.
- Ensuring defective or damaged PPE is immediately replaced.
- Conducting periodic workplace reassessments when new hazards are introduced or when processes are added or changed.
- Maintaining records on hazard assessments.
- Providing guidance for the selection and purchase of approved PPE.
- Periodically reevaluating the suitability of previously selected PPE.
- Reviewing, updating, and evaluating the overall effectiveness of their specific PPE Program.

4.3 Employees

Employees are typically the PPE user and therefore are responsible for following the requirements of their companies individual PPE Program. This involves:

- Wearing PPE as required and when required.
- Performing required training.
- Caring for, cleaning, and maintaining PPE as required.
- Informing the supervisor of the need to repair or replace PPE.
- Observing and coaching other employees to encourage safe behaviors.
- Utilizing individual “Stop Work” authority if unsafe conditions exist. Note: It is important to recognize that PPE will not save you if conditions are inherently unsafe. PPE is just a line of defense.

5 CLEANING AND MAINTENANCE OF PPE

It is important that all PPE be kept clean and properly maintained. Cleaning is particularly important for eye and face protection: dirty or fogged lenses could impair vision: a contaminant could be ingested, inhaled, or absorbed through exposed skin or mucus membranes. PPE should be inspected, cleaned, and maintained at regular intervals so that the PPE provides the requisite protection. Personal protective equipment should not be shared between employees until it has been properly cleaned and sanitized. PPE should be distributed for individual use whenever possible.

It is also important to ensure that contaminated PPE, which cannot be decontaminated, is disposed of in a manner that protects employees from exposure to hazards.

6 EYE AND FACE PROTECTION

Prevention of eye injuries requires that all persons who may be in eye hazard areas wear protective eyewear. This includes employees, visitors, researchers, contractors, or others passing through an identified eye hazard area. Note: any place where thermal spray is conducted is an eye hazard area. To provide protection for these personnel, a sufficient quantity of goggles and/or plastic eye protectors should be available. If personnel wear personal glasses, eye protectors suitable to wear over them should be provided. Five common categories of protective eyewear are defined below. Signs indicating that an area requires use of eye protection should be posted. Safety glasses should be made available at all access points to the eye protection area.

6.1 Safety Glasses

Protective eyeglasses are made with safety frames, tempered glass or plastic lenses, temples and side shields which provide eye protection from moderate impact and particles encountered in job tasks such as carpentry, woodworking, grinding, scaling, etc. Safety glasses are also available in prescription form for those persons who need corrective lenses. Personnel requiring prescription safety glasses should follow their corporate procedures obtaining PPE to obtain their prescription safety glasses.

6.2 Single Lens Goggles

Vinyl framed goggles of soft pliable body design provide adequate eye protection from many hazards. These goggles are available with clear or tinted lenses, perforated, port vented, or non-vented frames. Single lens goggles provide similar protection to spectacles and may be worn in combination with spectacles or corrective lenses to insure protection along with proper vision.

6.3 Welders/Chippers Goggles

These goggles are available in rigid and soft frames to accommodate single or two eyepiece lenses.

Welder’s goggles provide protection from sparking, scaling, or splashing metals and harmful light rays. Lenses

are impact resistant and are available in incremental shades of filtration.

Chippers/Grinders goggles provide eye protection from flying particles. The dual protective eye cups house impact resistant clear lenses with individual cover plates.

6.4 Face Shields

These normally consist of an adjustable headgear and face shield of tinted/transparent acetate or polycarbonate materials, or wire screen. Face shields are available in various sizes, tensile strength, impact/heat resistance and light ray filtering capacity. Face shields will be used in operations when the entire face needs protection and should be worn to protect eyes and face against flying particles, metal sparks, and chemical/biological splash.

6.5 Welding Shields

These shield assemblies consist of vulcanized fiber or glass fiber body, a ratchet/button type adjustable headgear or cap attachment and a filter and cover plate holder. These shields will be provided to protect workers' eyes and face from ultraviolet, infrared, or radiant light burns, flying sparks, metal spatter and slag chips encountered during welding, brazing, soldering, resistance welding, bare or shielded electric arc welding and oxyacetylene welding, oxyacetylene cutting operations, flame spray operations, electric arc spray operations, and plasma spray operations.

6.6 Additional Protection

Additional protection is needed when employees are exposed to hazards from flying particles, molten metal, acids or caustic liquids, chemical liquids, gases, or vapors, bio-aerosols, or potentially injurious light radiation such as that produced by some lasers.

- Wearers of contact lenses must also wear appropriate eye and face protection devices in a hazardous environment.
- The nature of the working environment should be considered before contact lenses are used. Contact lenses should not be used in an environment that could react with the contact lenses (e.g. working around chemical vapors that could react with the lens material)
- Side protectors are needed when there is a hazard from flying objects.
- Goggles and face shields are needed when there is a hazard from chemical splash.
- Face shields must always be worn over primary eye protection (safety glasses or goggles).
- For employees who wear prescription lenses, eye protectors need to either incorporate the prescription in the design or fit properly over the prescription lenses.
- Protectors shall be marked to identify the manufacturer.
- Equipment fitted with appropriate filter lenses need to be used to protect against light radiation (e.g. from an air plasma spray torch). Tinted and shaded lenses are not filter lenses unless they are marked or identified as such. Specifically, sunglasses do not adequately filter out the intense light from thermal spray processes and should not be considered protective filtering eyewear.

6.7 Prescription Safety Eyewear

OSHA regulations require that each affected employee who wears prescription lenses while engaged in operations that involve eye hazards shall wear eye protection that incorporates the prescription in its design, shall wear eye protection that can be worn over the prescription lenses (goggles, face shields) without disturbing the proper position of the prescription lenses or the protective lenses.

6.8 Eye Protection Cleaning and Maintenance

The lenses of eye protectors must be kept clean as dirty lenses restrict vision, which can cause eye fatigue and lead to accidents. Scratched eye protectors or those that cannot be cleaned should be discarded. There are two methods for cleaning eye protectors. Glass, polycarbonate and other plastic lenses can be cleaned by thoroughly wetting both sides of the lenses and drying them with a wet strength absorbent paper. Anti-static and anti-fog lens cleaning fluids may be used, daily if necessary, if static or misting is a problem. Alternatively lenses can be 'dry' cleaned by removing grit with a brush and using a silicone treated non-woven cloth. However plastic or polycarbonate lenses should not be 'dry' cleaned as the cloth used in this method can scratch them.

Eye protectors should be issued on a personal basis and used only by the person they are issued to. If eye protectors are re-issued they should be thoroughly cleaned and disinfected. Being placed in suitable cases when not in use should protect eye protectors.

Eye protector headbands should be replaced when worn out or damaged. Lenses that are scratched or pitted must be replaced as they may impair vision and their resistance to impact may be impaired. Transparent face-shields must be replaced when warped, scratched or have become brittle with age.

See the Eye and Face Protection Selection Chart on the following page.

Eye and Face Protection Selection Chart		
Source	**Assessment of Hazard**	**Eye and Face Protection**
IMPACT - Chipping, grinding, machining, drilling, chiseling, riveting, sanding, grit blasting, etc.	Flying fragments, flying objects, large chips, particles, sand, dirt, grit, dust etc…	Spectacles with side protection or goggles worn underneath a face shield. *Note: Grit blasting operations may require respiratory protection to mitigate lung hazards from respiratory dust, See Section 10*
CHEMICALS - Acid and chemicals handling, substrate cleaning, and rinsing	Splash, Irritating vapors, hazardous vapors	Goggles, eyecup and cover types worn underneath a face shield.
DUST – Grit Blasting, buffing, spray hood clean-up, general dusty conditions	Nuisance dust	Goggles, eyecup and cover types. *Note: Respiratory protection may also be required to mitigate lung hazards from respiratory dust. See Section 10*
LIGHT and/or UV RADIATION – Electric Arc, Plasma Spray, and electric arc welding	Optical radiation	Welding helmets or welding shields. Typical shades: 10-14, Auto-dimming shades as suitable. *Note: Skin protection to prevent UV burns (severe sunburn) is needed in addition to eye & face protection when working around Wire Arc, Plasma, and Welding process.*
Flame Spray, HVOF, and gas flame welding	Optical radiation	Welding goggles or welding face shield. Typical shades: gas welding 4-8, cutting 3-6, brazing 3-4
Cutting, torch brazing, torch soldering,	Optical radiation	Spectacles or welding face shield. Typical shades: 1.5-3 Auto-dimming shades as suitable.
Glare	Poor vision	Spectacles with shaded or special-purpose lenses, as suitable. Auto-dimming shades as suitable.

6.9 Emergency Eyewash & Shower Facilities

Emergency eyewash facilities meeting the requirements of ANSI Z358.1 need to be provided in all areas where the eyes of any employee may be exposed to corrosive materials. Eye wash facilities need to be located where they are easily accessible in an emergency. Permanently plumbed eyewashes are preferred, however portable eyewash stations are available for areas where plumbing isn't available. Periodic tests and inspections (see current ANSI Standard) should be conducted for all plumbed and mobile eyewash systems. A record should be kept documenting eyewash inspection/refill. Emergency shower facilities should also be considered when employees may be exposed to corrosive materials.

7 HEAD PROTECTION

Head injuries are caused by falling or flying objects, or by bumping the head against a fixed object. Head protectors, in the form or protective hats, must resist penetration and absorb the shock of a blow. The shell of

the protective hat is hard enough to resist the blow and the headband and crown straps keep the shell away from the wearer's skull. Protective hats can also protect against electrical shock.

Head protection needs to be furnished to, and used by, all personnel engaged in construction type work or other general industry work where overhead hazards exist: especially when spraying the interior surfaces of a large space, applying coatings overhead, or working with cranes and forklifts. Head protection should also be worn by engineers, inspectors, and visitors at construction sites when hazards from falling or fixed objects, or electrical shock are present. Bump caps/skull guards may be issued and worn for protection against scalp lacerations from contact with sharp objects. However, they must not be worn as substitutes for safety caps/hats because they do not afford protection from high impact forces or penetration by falling objects. Hard hat areas should always be clearly posted.

Protective hats are made in the following types and classes:

- Type I - Helmets with a full brim.
- Type 2 - Brimless helmets with a peak extending forward from the crown.
- Class A - General service, limited voltage: Intended for protection against impact hazards. Used in mining, construction, and manufacturing.
- Class B - Utility service, high voltage. Used by electrical workers.
- Class C - Special service, no voltage protection: Designed for lightweight comfort and impact protection. Used in certain construction, manufacturing, refineries, and where there is a possibility of bumping the head against a fixed object.

All head protection (helmets) is designed to provide protection from impact and penetration hazards caused by falling objects. Head protection is also available which provides protection from electric shock and burn. When selecting head protection, knowledge of potential electrical hazards is important. Class A helmets, in addition to impact and penetration resistance, provide electrical protection from low-voltage conductors (they are proof tested to 2,200 volts). Class B helmets, in addition to impact and penetration resistance, provide electrical protection from high-voltage conductors (they are proof tested to 20,000 volts). Class C helmets provide impact and penetration resistance (they are usually made of aluminum which conducts electricity), and should not be used around electrical hazards.

7.1 Head Protection Cleaning and Maintenance

Head protection must be maintained in good condition. It should:

- Be stored, when not in use, in a safe place, for example, on a peg or in a cupboard. It should not be stored in direct sunlight or in excessively hot, humid conditions;
- Be visually inspected regularly for signs of damage or deterioration;
    - Have defective harness components replaced (if the design or model allows this). Harnesses from one design or model of helmet cannot normally be interchanged with those from another;
    - Have the sweatband regularly cleaned or replaced.

7.1.1 Damage to shell

Damage to the shell of a helmet can occur when:

- Objects fall onto it;
- It strikes against a fixed object.
- It is dropped or thrown.

7.1.2 Deterioration in shock absorption or penetration resistance

Deterioration in shock absorption or penetration resistance of the shell can occur from:

- Exposure to certain chemical agents.

- Exposure to heat or sunlight.
- Aging due to heat, humidity, sunlight and rain.

7.1.3 Other Considerations

Before head protection is reissued to another person, it should be inspected to ensure it is serviceable and thoroughly cleaned in accordance with the manufacturer's instructions, e.g. using soap and water. The sweatband should always be cleaned or replaced.

Chemical agents that should be avoided include paint, adhesives or chemical cleaning agents. Where names or other markings need to be applied using adhesives, advice on how to do this safely should be sought from the helmet manufacturer.

Exposure to heat or sunlight can make the shell become brittle. Head protection should therefore never be stored near a window, e.g. the rear window of a motor vehicle, because excessive heat may build up.

7.1.4 Replacement

The head protection should normally be replaced at intervals recommended by the manufacturer. It will also need replacing when the harness is damaged and cannot be replaced, or when the shell is damaged or it is suspected that its shock absorption or penetration resistance has deteriorated - for example when:

- The shell has received a severe impact.
- Deep scratches occur.
- The shell has any cracks visible to the naked eye.

8 FOOT PROTECTION

Safety shoes need to be worn in areas where heavy materials could fall or roll on the feet or where puncture protection is required. All safety footwear needs to comply with ANSI Z41-1991, "American National Standard for Personal Protection - Protective Footwear." And ASTM F2413: “Standard specification for performance requirements for foot protection”.

Safety shoes or boots with impact protection need to be worn in work areas where carrying or handling materials such as packages, objects, parts or heavy tools, which could be dropped; and for other activities where objects might fall onto the feet. Safety shoes or boots with compression protection are typically required for work activities involving skid trucks (manual materials handling cars) or other activities in which materials or equipment could potentially roll over an employee’s feet. Safety shoes or boots with puncture protection are required where sharp objects such as nails, wire, tacks, screws, large staples, scrap metal etc., could be stepped on by employees causing a foot injury.

8.1 Safety Footwear Cleaning and Maintenance

Safety footwear should be maintained in good condition, checked regularly and discarded if worn or deteriorated. Laces should be checked and replaced if necessary. Materials lodged into the tread should be removed. The stitching should be checked for loose, worn or cut seams. Spraying the upper layers of new footwear with a silicone spray or applying a protective wax will give extra protection against wet conditions.

There are many types and styles of protective footwear and it’s important to realize that a particular job may require additional protection other than listed here. Footwear that meets established safety standards will have an American National Standards Institute (ANSI) label inside each shoe.

1. Steel-Reinforced Safety Shoes. These shoes are designed to protect feet from common machinery hazards such as falling or rolling objects, cuts, and punctures. The entire toe box and insole are reinforced with steel, and steel, aluminum, or plastic materials protect the instep. Safety shoes are also designed to insulate against temperature extremes and may be equipped with special soles to guard against slip, chemicals, and/or electrical hazards.
2. Safety Boots. Safety boots offer more protection when splash or spark hazards (chemicals, molten

materials) are present:

3. When working with corrosives, caustics, cutting oils, and petroleum products, neoprene or nitrile boots are often required to prevent penetration.
4. Foundry or "Gaiter" style boots feature quick-release fasteners or elasticized insets to allow speedy removal should any hazardous substances get into the boot itself.
5. When working with electricity, special electrical hazard boots are available and are designed with no conductive materials other than the steel toe (which is properly insulated).

Safety shoes and boots which meet the ANSI Z41-1991 Standard provide both impact and compression protection. Where necessary, safety shoes can be obtained which provide puncture protection. In some work situations, metatarsal protection should be provided, and in other special situations electrical conductive or insulating safety shoes would be appropriate.

9 HAND PROTECTION

Suitable gloves need be worn when hazards from chemicals, cuts, lacerations, abrasions, punctures, burns, biological agents, and harmful temperature extremes are present. Glove selection shall be based on performance characteristics of the gloves, conditions, duration of use, and hazards present. Any one type of glove will not work in all situations. Skin contact is a potential source of exposure with toxic materials; it is important that the proper steps be taken to prevent such contact. Most accidents involving hands and arms can be classified under four main hazard categories: chemicals, abrasions, cutting, and heat. There are gloves available that can protect workers from any of these individual hazards or any combination thereof.

Gloves should also be worn whenever it is necessary to handle rough or sharp-edged objects, and very hot or very cold materials. The types of glove materials to be used in these situations include leather, welder's gloves, aluminum-backed gloves, and other types of insulated glove materials.

The first consideration in the selection of gloves for use against chemicals is to determine, if possible, the exact nature of the substances to be encountered. Read instructions and warnings on chemical container labels and MSDS's before working with any chemical. Recommended glove types are often listed in the section for personal protective equipment.

Chemicals eventually permeate all glove materials. However, they can be used safely for limited time periods if specific use and other characteristics (i.e., thickness and permeation rate and time) are known.

Careful attention must be given to hand protection when working with tools and machinery. Power tools and machinery must have guards installed or incorporated into their design that prevent the hands and gloves from contacting the point of operation, power train, or other moving parts. To protect hands from injury due to contact with moving parts, it is important to:

- Ensure that guards are always in place and used.
- Always lockout machines or tools and disconnect the power before making repairs.
- Treat a machine without a guard as inoperative; and
- Do not wear gloves around moving machinery, such as drill presses, mills, lathes, and grinders.

The following is a guide to the most common types of protective work gloves and the types of hazards they can guard against:

- Disposable Gloves. Disposable gloves, usually made of lightweight plastic, can help guard against mild irritants. Disposable gloves are often used for powder handling and for general hand protection when working with dusty equipment in a spray booth because they prevent nuisance dusts and powders from contacting the skin.
- Fabric Gloves. Made of cotton or fabric blends are generally used to improve grip when handling slippery objects. They also help insulate hands from mild heat or cold.
- Leather Gloves. These gloves are used to guard against injuries from sparks or scraping against

rough surfaces. They are also used in combination with an insulated liner when working with electricity. Leather gloves should be used when hand spraying and may be sometimes be used when handling hot parts.

- Metal Mesh Gloves. These gloves are used to protect hands form accidental cuts and scratches and are most commonly used when working with cutting tools or other sharp instruments.
- Aluminized Gloves. Gloves made of aluminized fabric are designed to insulate hands from intense heat. Persons working molten materials most commonly use these gloves. Aluminized gloves can be used as an alternative to leather gloves when handling hot parts.
- Chemical Resistance Gloves. These gloves may be made of rubber, neoprene, polyvinyl alcohol or vinyl, etc. The gloves protect hands from corrosives, oils, and solvents. The table in Appendix A is provided as a guide to the different types of glove materials and the chemicals they can be used against. When selecting chemical resistance gloves, be sure to consult the manufacturers' recommendations, especially if the gloved hand will be immersed in the chemical.
- Electrical Gloves. These gloves are made of natural rubber and are designed to protect the wearer against electrical current. Leather protectors must be worn over gloves when voltage exceeds 250 volts. Leather protectors provide puncture, abrasion, and moisture resistance. Note: If electrical gloves are used as PPE for working on a live electrical circuit it is important to consult NFPA 70E to determine the Hazard Risk Category and the type of glove required. **See the Section in this document on Arc Flash.**

9.1 Glove Cleaning and Maintenance

Care should be taken in the donning, use, removal and storage of protective gloves. They should be maintained in good condition, checked regularly and discarded if worn or deteriorated. Gloves should be free of holes or cuts and foreign materials and their shape should not be distorted. They should fit the wearer properly leaving no gap between the glove and the wearer's sleeve.

Gloves should be replaced periodically, depending on frequency of use and permeability to the substance(s) handled. Contaminated gloves should be rinsed and then carefully removed after use. For the purposes of compliance with OSHA CFR 1910.132 (a) and (b), PPE should be inspected, cleaned, and maintained at regular intervals so that the PPE provides the requisite protection. It is also important to ensure that contaminated PPE which cannot be decontaminated is disposed of in a manner that protects employees and the environment from exposure to hazards. [59 FR 16362, April 6, 1994]

Gloves should always be cleaned according to the manufacturer's instructions as they may have particular finishes that may make the following general guidance inappropriate. For example, repeated washing may remove fungal and bacterial inhibitors from the lining of the glove that may ultimately lead to skin irritation. And there is also the risk of cross contamination as chemical residues can remain on the gloves even after washing.

Contact between the gloves and chemicals should be kept to a minimum as some chemicals can alter the physical characteristics of a glove and impair its protective properties. Gloves contaminated by chemicals should be washed as soon as possible and before their removal from the hands.

Grossly contaminated gloves should be discarded. Gloves contaminated on the inside can be dangerous, as the skin will absorb the chemical contamination. Wear armlets if there is a danger of chemicals entering the glove at the cuff.

When wearing protective gloves do not touch other exposed parts of the body, equipment or furniture as contamination can be transferred to them. Cotton liners can be worn if hands sweat profusely.

10 RESPIRATORY PROTECTION

Respirators are devices that protect the wearer from inhaling dangerous substances such as particulates, fumes, vapors, and gases. There are a wide variety of respiratory protection devices available. The two main

categories are *air-purifying* and *air-supplied* respirators. It is critical to select the proper type of respiratory protective equipment, to supply it to workers, and to train workers to use it correctly.

An air monitoring program **must** be conducted to determine type and level of chemical exposure and what level of protection is required. If respirators are required then a formal respiratory protection program be set up for workers. An industrial hygiene professional should be be consulted as part of the process.

Respiratory protection must be considered for several thermal spray activities. The most common respiratory hazards associated with thermal spray are particulates and fumes:

- Surface preparation techniques, for example grit blasting, can also generate fine particulates of the grit medium and of the substrate. These particles can be inhaled by the worker and do present a respiratory hazard.
- Sand blasting with silicon dioxide creates a cloud of particles that should not be breathed.
- Loading and emptying grit blast cabinets should be done while wearing the proper respirator.
- Powder handling activities such as loading, unloading, and cleaning hoppers should similarly be performed with respirators.
- The thermal spray operation itself potentially exposes the worker to the feedstock particulate as well as to fumes produced by the vaporization and condensation of the feedstock.

Appropriate respiratory protection should always be used when hand spraying or working around an operating spray device. Cleaning operations within the thermal spray enclosure should always be performed with the awareness that fine particulates will be stirred up and inhaled by unprotected workers. Vapors from solvents can also be of concern since they are often used during the part-cleaning process. The respiratory threats posed by thermal spray activities can introduce either acute or chronic risks to the worker that have to be mitigated.

In general, it is **recommended** that engineering and administrative controls be introduced to minimize worker exposure to respiratory hazards. For example, not entering a spray booth after a part has been coated until several air exchanges have been completed is a method that can be used to reduce exposure. A respiratory protection program should train workers as to what type of protection to wear, when to wear it, and how to properly wear and care for the equipment.

10.1 Air purifying respirators

Air-purifying respirators are typically negative pressure units in which the user's inhalation draws contaminated air in through a filtration medium and exhalation pushes air out through one-way valves back into the atmosphere. Straps are used to hold the respirator in place on the wearer's head. A half-face mask that covers the nose and mouth is the most commonly used style for thermal spray operations. Full-face masks are used whenever the contaminant in the air can harm the eyes or rest of the face, or when a higher protection factor is required.

Cloth or paper nuisance dust masks, similar in style to surgical masks, are tempting to use because they are inexpensive; however, they do not provide adequate protection for thermal spray operations and should not be used.

Air-purifying respirators typically use a pair of replaceable filter cartridges. There are several different types of cartridges to choose from, depending on the contaminant in the air. Some cartridges remove particles from the air, others remove organic vapors given off by solvents, while still others can handle chemical vapors such as acid fumes. Combination filters that remove both organic vapors and suspended particles are also available, if they are needed. It is essential that the correct cartridge type is chosen for the worker to wear. It should also be recognized that all cartridges have to be replaced periodically.

Particulate filtering is the most common need in thermal spray operations. Particles in the size range of ~0.3 microns are the most difficult to filter out of the air. Coarser particles get embedded in the filter medium as air is drawn through it. Finer particles get trapped by Brownian motion in the filter material. Particles that are a few tenths of a micron in diameter penetrate most deeply through the filter and are of the greatest concern. The lower end of powder size distributions often contain quantities of submicron-sized particles. Fumes from partially vaporized powders and atomized wire droplets also contain particles in this size range. In order to

ensure that optimal protection is provided to the worker, it is important that the mask fits properly and is well maintained. It is also important that the correct cartridges are chosen and that they are replaced as needed.

10.2 Air-supplied respirators

In an air-supplied respirator the worker typically wears a half- or full-face mask and breathable air is supplied via a pressurized airline. The air can come from a tank with a regulator and pressure gauge that is carried by the operator, in which case the unit is considered to be a self-contained breathing apparatus. Alternatively, the air is provided by a specially designed compressor that filters the air and supplies it to the worker via a long hose or through a specially designated piping system with a manifold that the hose is connected to. Conventional “house air” or “compressed air” available at all thermal spray facilities to run grit blasters, and so on, should never be used to supply breathing air to workers, because of lubricant and particulate that are suspended in the air stream.

10.3 Respiratory Protection Summary

Respiratory PPE must be considered for all thermal spray facilities. Particulates of many kinds and sources are the most significant hazard, but solvents and chemical vapors and fumes should also be evaluated when setting up a respiratory protection program. It should be recognized that respirators do not eliminate operator exposure to contaminated air; rather they reduce it by some factor that depends on the properness of the respirator’s fit, the concentration of the contaminant in the air, the type of respirator being used, and so on. Operational procedures in the form of engineering and administrative controls should be put in place to reduce or eliminate the need for respiratory PPE and to limit the concentration of contaminants that workers are exposed to. It is highly recommended that an industrial hygienist be consulted when addressing respiratory protection issues.

11 HEARING PROECTION

In accordance with OSHA 1910.95, it is required that employees are protected from noise levels above 85 dBA, time weighted average, during a normal eight hour workday.

Thermal spray processes generally exceed 85 dBA and can exceed 125 dBA. Because of the nature of most thermal spray businesses, operators, supervisors, quality inspectors, maintenance, and occasionally office workers are exposed to these levels of noise. Therefore, we recommend that all persons working in spray shop areas be required to wear either earplugs or earmuffs with the highest Noise Reduction Rating (NRR) available. These persons include operators, supervisors, outside contractors, and inspection personnel. As a best practice visitors who are taking short tours, delivery personnel, and office personnel who are passing through the area should also wear hearing protection.

Every employee, who is required to wear hearing protection, in the performance of his or her duties, must participate in a hearing conservation program that includes yearly auditory testing to insure the effectiveness of the Hearing Protection Program.

Ear plugs and earmuffs should be provided by the employer to all who require them at no cost. The employer should also bear the cost of the annual auditory testing.

11.1 High Noise Areas

There are areas and circumstances associated with many thermal spray operations where noise levels are higher than those associated with conventional thermal spray processes. These include the High Velocity Oxy- Fuel (HVOF) spray operations, high-energy plasma-arc spraying, and high-energy electric arc spray (EAS) as well as detonation processes. In these areas and with these processes, noise levels meet and can exceed 125 dBA. In these areas and with these processes, both earplugs AND earmuffs are required. The NRR for hearing protection devices is not arithmetically additive (only logarithmically) and neither OSHA nor NIOSH recognize the full NRR given by manufacturers of these devices, because of variances in fitting.

The following are examples of situations where both earplugs AND earmuffs must be worn.

- When either hand spraying, entering a booth during spraying, or working around a spray booth that has open doors or frequently opened doors or access panels while spraying with:
    - HVOF,
    - Argon-helium plasma-arc where gas flow and current are equal to or higher than [Ar 130-150 psi (234-267 scfh), He 150-200 psi (74-99 scfh), 900 Amps DC],
    - Using Argon-hydrogen plasmas
    - Using nitrogen as a primary plasma-arc gas, or
    - EAS with air pressures above 80 psi with current levels above 200 Amps DC and any operating current above 100 psi air pressure.

As mentioned above, the NRR value for plugs and muffs cannot be applied directly to the noise field and the NRR's of plugs and muffs are NOT arithmetically additive when used together. For example, if hearing protection has an NRR of 25, and is used in a noise field of 125 dBA, the exposure is NOT reduced to 100 dBA. Likewise, if plugs and muffs are used, each with an NRR of 25 the combined NRR is NOT 50. See below for further explanation.

MSHA, NIOSH, and OSHA do not treat the effectiveness the same way. The following is the guideline that the Thermal Spray Safety Committee recommends based on our best understanding of the issues at hand. The effectiveness of either plugs or muffs should be calculated using the following formula:

Effective NRR = (NRR-7) / 2

Therefore the use of ear plugs with an NRR of 29 provides the following Effective NRR:

Effective NRR = (29-7) / 2 = 11 dBA reduction

Additive Example of double protection:

As stated above the use of ear plugs with an NRR of 29 provides the following Effective NRR:

Effective NRR = (29-7) / 2 = 11 dBA reduction

The addition of a second level of protection, for example earmuffs with an NRR of 29, would double the overall effectiveness of the combined hearing protection. However, because sound is measured on a logarithmic scale a doubling of effectiveness is equivalent to an additional 3 dBA reduction. Therefore the total effectiveness of ear plugs AND ear muffs would be:

11 dBA (plugs) + an additional 3 dBA (muffs) = 14 dBA

In accordance with OSHA, there can be no unprotected exposure above 90 dBA TWA. Using the above calculation, the operator could be exposed to 90 + 14 = 104 dBA TWA for 8 hours.

Continuous exposure to HVOF at 125 dBA would follow this calculation.

125 dBA – 14 dBA = 111 dBA

In accordance with OSHA noise exposure tables, under these conditions, an operator would be limited to a maximum of 30 minutes in an eight-hour period.

12 ELECTRICAL / ARC FLASH PROTECTION

General electrical safety

Voltages as low as 12 volts can be dangerous. When working with or around electrical equipment one may inadvertently become part of an electrical circuit. Only trained and authorized or qualified individuals should do any repair or work on electrical equipment.

As part of a Company's Health and Safety Program a hazard analysis of the workplace should be conducted. This analysis will provide a mechanism for defining work-unit-specific hazards associated with working with electricity, and create a plan for hazard mitigation and employee training.

Generally thermal spray operators will not be directly servicing live electrical equipment associated with the thermal spray equipment. However servicing and maintenance operations may be going on in the shop areas around thermal spray equipment and personnel in the area need to be aware of the hazards and needed PPE if they are potentially exposed.

Arc Flash is a significant hazard associated with working on or around live electrical equipment. The following section describes Arc Flash and needed PPE for authorized and affected personnel.

ARC FLASH

Simply put, an arc flash is a phenomenon where a flashover of electric current leaves its intended path and travels through the air from one conductor to another, or to ground. The results are often violent and when a human is in close proximity to the arc flash, serious injury and even death can occur.

Arc flash can be caused by many things including:

- Dust
- Dropping tools
- Accidental touching
- Condensation
- Material failure
- Corrosion
- Faulty Installation
- Three factors determine the severity of an arc flash injury:
- Proximity of the worker to the hazard
- Temperature
- Time for circuit to break

Because of the violent nature of an arc flash exposure when an employee is injured, the injury is serious – even resulting in death. It's not uncommon for an injured employee to never regain their past quality of life. Extended medical care is often required, sometimes costing in excess of $1,000,000.

Typical Results from an Arc Flash

- Burns (Non Fire Rated clothing can burn onto skin)
- Fire (could spread rapidly through building)
- Flying objects (often molten metal)
- Blast pressure (upwards of 2,000 lbs. / sq. ft.)
- Sound Blast (noise can reach 140 dB – as loud as a gun)
- Heat (upwards of 35,000 degrees F)

Approach / Protection Boundaries

The National Fire Protection Association (NFPA) has developed specific approach boundaries designed to protect employees while working on or near energized equipment. These boundaries are:

- **Flash Protection Boundary (outer boundary)**

- **Limited Approach**
- **Restricted Approach**
- **Prohibited Approach (inner boundary)**

Flash Protection Boundary (outer boundary): The flash boundary is the farthest established boundary from the energy source. If an arc flash occurs this boundary is where an employee would be exposed to a curable second degree burn (1.2 calories/cm2). The issue here is that the heat generated from a flash results in burns.

Limited Approach: This is an approach limit at a distance from an exposed live part where a shock hazard exists.

Restricted Approach: This is an approach limit at a distance from an exposed live part which there is an increased risk of shock.

Prohibited Approach (inner boundary): This is a distance from an exposed part which is considered the same as making contact with the live part. This distance is not common between equipment. Some equipment will have a greater flash protection boundary while other equipment will have a lesser boundary.

Ways to Protect the Workers

There exists a number of ways to protect workers from the threat of electrical hazards. Some of the methods are for the protection of qualified employees doing work on electrical circuit and other methods are geared towards non-qualified employees who work nearby energized equipment.

Here are a few of the protective methods:

- De-energize the circuit
- Work Practices
- Insulation
- Guarding
- Barricades
- Ground Fault Circuit Interrupters (GFCI)
- Grounding (secondary protection)

If You Must Work on Energized Circuits

If it has been determined that de-energizing a circuit is not feasible and the employee must work “hot”, the employer shall develop and enforce safety-related work practices to prevent electric shock or other injuries resulting from either direct or indirect electrical contacts. The specific safety-related work practices shall be consistent with the nature and extent of the associated electrical hazards.

These safety related work practices could include:

- Energized Electrical Work Permit
- Personal Protective Equipment
- Insulated Tools
- Written Safety Program
- Job Briefing

The most effective and fool-proof way to eliminate the risk of electrical shock or arc flash is to simply de-energize the equipment.

Understanding the Arc Flash Warning Labels

Each piece of equipment operating at 50 volts or more and not put into a de-energized state must be evaluated for arc flash and shock protection. This evaluation will determine the actual boundaries (i.e. prohibited, limited, restricted, etc.) and will inform the employee of what PPE must be worn.

Once the evaluation is complete an Arc Flash Hazard warning label must be affixed to the equipment and readily accessible to employees who may work on the energized equipment.

The Employees Obligation

Employees must follow the requirements of the Arc Flash Hazard label by wearing the proper personal protective equipment (PPE), use of insulated tools and other safety related precautions. This includes not working on or near the circuit unless you are a “qualified” person.

Qualified person: One who has received training in and has demonstrated skills and knowledge in the construction and operation of electric equipment and installations and the hazards involved. Qualified persons (i.e. those permitted to work on or near exposed energized parts) shall also, at a minimum, be trained in and familiar with the following:

- The skills and techniques necessary to distinguish exposed live parts from other parts of electric equipment.
- The skills and techniques necessary to determine the nominal voltage of exposed live parts, and
- The clearance distances specified in 1910.333(c) and the corresponding voltages to which the qualified person will be exposed.

See the Table of Arc Flash PPE requirements on the following page.

Arc Flash PPE Requirements from 2012 NFPA 70E

Level 0	Level 1	Level 2	Level 3	Level 4
Protective Clothing: Non-melting or Untreated Natural Fiber (i.e. untreated cotton, wool, rayon, or silk, or blends of these materials) With a fabric weight of at least 4.5 oz/yd² • Shirt (long sleeve) • Pants (long)	**Protective Clothing:** Arc-rated clothing, minimum arc rating of 4 cal/cm² (See Note 3.) • Arc-rated long-sleeve shirt and pants or arc-rated coverall • Arc-rated face shield (See Note 2.) or arc flash suit hood • Arc-rated jacket, parka, rainwear, or hard hat liner (AN)	**Protective Clothing:** Arc-rated clothing, minimum arc rating of 8 cal/cm² (See Note 3.) • Arc-rated long-sleeve shirt and pants or arc-rated coverall • Arc-rated flash suit hood or arc-rated face shield (See Note 2.) and arc-rated balaclava • Arc-rated jacket, parka, rainwear, or hard hat liner (AN)	**Protective Clothing:** Arc-rated clothing selected so that the system arc rating meets the required minimum arc rating of 25 cal/cm² (See Note 3.) • Arc-rated long-sleeve shirt (AR) • Arc-rated pants (AR) • Arc-rated coverall (AR) • Arc-rated arc flash jacket (AR) • Arc-rated arc flash pants (AR) • Arc-rated arc flash suit hood • Arc-rated gloves (See Note 1.) • Arc-rated jacket, parka, rainwear, or hard hat liner (AN)	**Protective Clothing:** Arc-rated clothing selected so that the system arc rating meets the required minimum arc rating of 40 cal/cm² (See Note 3.) • Arc-rated long-sleeve shirt (AR) • Arc-rated pants (AR) • Arc-rated coverall (AR) • Arc-rated arc flash suit pants (AR) • Arc-rated arc flash suit jacket (AR) • Arc-rated arc flash suit hood • Arc-rated gloves (See Note 1.) • Arc-rated jacket, parka, rainwear, or hard hat liner (AN)
Protective Equipment: • Safety glasses or safety goggles (SR) • Hearing protection (ear canal inserts) • Heavy duty leather gloves (AN) (See Note 1.) .	**Protective Equipment:** • Hard Hat • Safety glasses or safety goggles (SR) • Hearing protection (ear canal inserts) • Heavy duty leather gloves (See Note 1.)	**Protective Equipment:** • Hard Hat • Safety glasses or safety goggles (SR) • Hearing protection (ear canal inserts) • Heavy duty leather gloves (See Note 1.) • Leather work shoes	**Protective Equipment:** • Hard Hat • Safety glasses or safety goggles (SR) • Hearing protection (ear canal inserts) • Leather work shoes	**Protective Equipment:** • Hard Hat • Safety glasses or safety goggles (SR) • Hearing protection (ear canal inserts) • Leather work shoes

AN = As needed (optional)
SR = Selection required
Note 1. If rubber insulating gloves with leather protectors are required by Table 130.7(C)(15)(a) or 130.7(C)(15)(b), additional leather or arc flash gloves are not required. The combination of rubber insulating gloves with leather protectors satisfies the arc flash protection requirement. Note 2. Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck or, alternatively, an arc–rated arc flash suit hood is required to be worn. Note 3. Arc rating is defined in Article 100 and can be either ATPV or EBT.

13 PERSONAL FALL PROTECTION

Employers must provide and ensure the use of fall protection and personal protective equipment (PPE) to their affected employees. They also have to train employees on how to properly use the equipment. OSHA's regulatory requirements were created to provide a minimum acceptable amount of protection for employees at your work sites, and additional protections should always be considered and evaluated.

As part of a Company's Health and Safety Program a hazard analysis of the workplace should be conducted. This analysis will provide a mechanism for defining work-unit-specific hazards associated with working with at heights and create a plan for hazard mitigation and employee training.

Whether it's the danger of falling, being exposed to airborne containments or flying debris, or a host of other hazards on the jobsite, employees must know how to select and use appropriate personal fall arrest systems and personal protective equipment.

- Understand OSHA's PPE/fall protection safety rules and regulations
- Outfit employees with the proper fall protection (arrest) systems and PPE attire
- Inform employees how to select fall protection systems appropriate for given situations
- Explain how to properly care for and maintain equipment
- Provide the necessary training for employees

OSHA requires employers in general industry to first address safeguards to the physical structures and devices within the workplace, and then use personal protective equipment (PPE) for employees when they are unable to completely control the hazards through engineering or administrative methods.

Fall protection standards for physical structures are located under the "walking and working surfaces" standards [29 CFR 1910, Subpart D]. These standards cover floor and wall openings/holes, elevated platforms, fixed stairs and fixed ladders. For each work surface, OSHA has established minimum construction requirements for safeguards such as railings, handrails and toe boards. The goals of these standards are to minimize:

- Employee falls, and
- Objects falling on employees from surfaces above their heads.

As a general rule, openings and platforms 4 feet or more above floor-level or fixed stairs with four or more risers must be constructed with railings and/or hand rails. The walking and working surfaces standards provide these specific instructions regarding the construction of these structures.

Toe boards must be installed on platforms and around openings whenever:

- Workers or visitors can pass beneath the platform, or
- The platform is above moving machinery, or
- There is equipment below the platform with which falling materials could create a hazard.

Also, open-sided floors and platforms require railings and toe boards – even if the elevation is under 4 feet – if they are above or adjacent to hazardous locations (e.g., dangerous equipment).

Unconventional Elevated Work Surfaces

Because there are many unconventional elevated working surfaces (i.e., conveyors, tops of machinery, tops of thermal spray booths, and other structures not normally considered "walking and working" surfaces), OSHA clarifies what it means by "platforms" at STD 1-1.13. According to this directive, OSHA considers something a platform, and therefore subject to the platform guarding standards, if employees will work on it on a "predictable and regular basis."

"Predictable and regular" covers functions such as, but not limited to, inspections, service, repair and maintenance that are performed at least once every 2 weeks or for a total of 4 man-hours during any sequential 4-week period. For instance, if two employees work for 2 hours each (4 man-hours total) within a 4-week period, that elevated surface would be considered a "platform."

Personal Protection Equipment

As a general rule, PPE must be provided, used and maintained in reliable conditions whenever hazards in the workplace can cause injury or impairment from physical contact [29 CFR 1910.132(a)]. If, after securing the workplace by installing mandatory safeguards, employees still are at risk from falling hazards, then employers must select, provide and train their employees in the proper use and care of their personal protective equipment.

The safety and health regulations for general industry do not have standards for specific fall protection PPE. However, there are specifications for certain fall prevention and fall arrest systems within the safety and health regulations for construction [29 CFR 1926). While these regulations may not directly apply to non-construction-related practices, they may serve as a basis for demonstrating the general requirements at 29 CFR 1910.132. In addition, there may be consensus standards that pertain to a workplace scenario that may provide assistance to the employer in assuring that fall protection PPE has been evaluated and implemented properly under the general industry regulations.

14 TRAINING

Any worker required to wear PPE shall receive training in the proper use and care of PPE. Periodic retraining shall be offered by EH&S to both the employees and the supervisors, as needed. The training shall include, but not necessarily be limited to, the following subjects:

- When and where PPE is necessary to be worn.
- What PPE is necessary?
- How to properly don, doff, adjust, and wear PPE.
- The limitations of the PPE.
- The proper care, maintenance, useful life and disposal of the PPE.

After the training, the employees shall demonstrate that they understand the components of the PPE Program and how to use PPE properly, or they shall be retrained.

15 RECORDKEEPING

Written records shall be kept of the names of persons trained, the type of training provided, and the dates when training occurred. The Supervisor should maintain their employees' training records for at least 3 years. The company should maintain the Hazard Assessment Certification Form for each work site evaluated for at least 3 years.

16 REFERENCES

American National Standards Institute, American National Standard ANSI Z41-1991, "Personnel Protection - Protective Footwear".

American National Standards Institute, American National Standard ANSI Z87.1-1989, "Practice for Occupational and Educational Eye and Face Protection".

American National Standards Institute, American National Standard ANSI Z89.1-1986, "Safety Requirements for Industrial Protection".

OSHA Standard 29 CFR 1910.132, "General Requirements"

OSHA Standard 29 CFR 1910.133, "Eye and Face Protection"

OSHA Standard 29 CFR 1910.135, "Head Protection"

OSHA Standard 29 CFR 1910.136, "Occupational Foot Protection"

OSHA Standard 29 CFR 1910.138, "Hand Protection"

OSAH 29 CRF 1910, subpart D, “Walking and Working Surfaces”

17 Appendices

17.1 Appendix A: Glove Chart

Type	Advantages	Disadvantages	Use Against
Natural rubber	Low cost, good physical properties, dexterity	Poor vs. oils, greases, organics. Frequently imported; may be poor quality	Bases, alcohol, dilute water solutions; fair vs. aldehydes, ketones.
Natural rubber blends	Low cost, dexterity, better chemical resistance than natural rubber vs. some chemicals	Physical properties frequently inferior to natural rubber	Same as natural rubber
Polyvinyl chloride (PVC)	Low cost, very good physical properties, medium cost, medium chemical resistance	Plasticizers can be stripped; frequently imported may be poor quality	Strong acids and bases, salts, other water solutions, alcohol
Neoprene	Medium cost, medium chemical resistance, medium physical properties	NA	Oxidizing acids, anilines, phenol, glycol ethers
Nitrile	Low cost, excellent physical properties, dexterity	Poor vs. benzene, methylene chloride, trichloroethylene, many ketones	Oils, greases, aliphatic chemicals, xylene, perchloroethylene, trichloroethane; fair vs. toluene
Butyl	Specialty glove, polar organics	Expensive, poor vs. hydrocarbons, chlorinated solvents	Glycol ethers, ketones, esters
Polyvinyl alcohol (PVA)	Specialty glove, resists a very broad range of organics, good physical properties	Very expensive, water sensitive, poor vs. light alcohol	Aliphatics, aromatics, chlorinated solvents, ketones (except acetone), esters, ethers
Fluoro-elastomer (Viton)	Specialty glove, organic solvents	Extremely expensive, poor physical properties, poor vs. some ketones, esters, amines	Aromatics, chlorinated solvents, also aliphatics and alcohols
Norfoil (Silver Shield)	Excellent chemical resistance	Poor fit, easily punctures, poor grip, stiff	Use for Hazmat work

17.2 Appendix B: Glove Type and Chemical Use

- *** Limited service**
- **VG= Very Good**
- **G= Good**
- **F=Fair**
- **P=Poor (not recommended)**

Chemical	Neoprene	Natural Latex or Rubber	Butyl	Nitrile Latex
*Acetaldehyde	VG	G	VG	G
Acetic acid	VG	VG	VG	VG
*Acetone	G	VG	VG	P
Ammonium hydroxide	VG	VG	VG	VG
*Amyl acetate	F	P	F	P
Aniline	G	F	F	P
*Benzaldehyde	F	F	G	G
*Benzene	F	F	F	P
Butyl acetate	G	F	F	P
Butyl alcohol	VG	VG	VG	VG
Carbon disulfide	F	F	F	F
*Carbon tetrachloride	F	P	P	G
Castor oil	F	P	F	VG
*Chlorobenzene	F	P	F	P
*Chloroform	G	P	P	E
Chloronaphthalene	F	P	F	F
Chromic Acid (50%)	F	P	F	F
Citric acid (10%)	VG	VG	VG	VG
Cyclohexanol	G	F	G	VG
*Dibutyl phthalate	G	P	G	G
Diesel fuel	G	P	P	VG
Diisobutyl ketone	P	F	G	P
Dimethylformamide	F	F	G	G
Dioctyl phthalate	G	P	F	VG
Dioxane	VG	G	G	G
Epoxy resins, dry	VG	VG	VG	VG
*Ethyl acetate	G	F	G	F
Ethyl alcohol	VG	VG	VG	VG
Ethyl ether	VG	G	VG	G
*Ethylene dichloride	F	P	F	P
Ethylene glycol	VG	VG	VG	VG
Formaldehyde	VG	VG	VG	VG
Formic acid	VG	VG	VG	VG
Freon 11	G	P	F	G
Freon 12	G	P	F	G
Freon 21	G	P	F	G
Freon 22	G	P	F	G
*Furfural	G	G	G	G
Gasoline, leaded	G	P	F	VG
Gasoline, unleaded	G	P	F	VG
Glycerine	VG	VG	VG	VG
Hexane	F	P	P	G
Hydrochloric acid	VG	G	G	G
Hydrofluoric acid (48%)	VG	G	G	G
Hydrogen peroxide (30%)	G	G	G	G
Hydroquinone	G	G	G	F
Isooctane	F	P	P	VG

Chemical	Neoprene	Natural Latex or Rubber	Butyl	Nitrile Latex
Isopropyl alcohol	VG	VG	VG	VG
Kerosene	VG	F	F	VG
Ketones	G	VG	VG	P
Lacquer thinners	G	F	F	P
Lactic acid (85%)	VG	VG	VG	VG
Lauric acid (36%)	VG	F	VG	VG
Lineoleic acid	VG	P	F	G
Linseed oil	VG	P	F	VG
Maleic acid	VG	VG	VG	VG
Methyl alcohol	VG	VG	VG	VG
Methylamine	F	F	G	G
Methyl bromide	G	F	G	F
*Methyl chloride	P	P	P	P
*Methyl ethyl ketone	G	G	VG	P
*Methyl isobutyl ketone	F	F	VG	P
Methyl methacrylate	G	G	VG	F
Monoethanolamine	VG	G	VG	VG
Morpholine	VG	VG	VG	G
Naphthalene	G	F	F	G
Naphthas, aromatic	G	P	P	G
*Nitric acid	G	F	F	F
Nitromethane (95.5%)	F	P	F	F
Nitropropane (95.5%)	F	P	F	F
Octyl alcohol	VG	VG	VG	VG
Oleic acid	VG	F	G	VG
Oxalic acid	VG	VG	VG	VG
Palmitic acid	VG	VG	VG	VG
Perchloric acid (60%)	VG	F	G	G
Perchloroethylene	F	P	P	G
Petroleum distillates (naphtha)	G	P	P	VG
Phenol	VG	F	G	F
Phosphoric acid	VG	G	VG	VG
Potassium hydroxide	VG	VG	VG	VG
Propyl acetate	G	F	G	F
Propyl alcohol	VG	VG	VG	VG
Propyl alcohol (iso)	VG	VG	VG	VG
Sodium hydroxide	VG	VG	VG	VG
Styrene	P	P	P	F
Stryene (100%)	P	P	P	F
Sulfuric acid	G	G	G	G
Tannic Acid (65%)	VG	VG	VG	VG
Tetrahydrofuran	P	F	F	F
*Toluene	F	P	P	F
Toluene diisocyanate	F	G	G	F
*Trichloroethylene	F	F	P	G
Triethanolamine	VG	G	G	VG
Tung Oil	VG	P	F	VG
Turpentine	G	F	F	VG
*Xylene	P	P	P	F

17.3 Appendix C: Job Hazard Analysis Example

This job hazard analysis is part of a written Hazard Communication Program designed to comply with OSHA's Hazard Communication Standard (29 CFR 1910.1200)

Job or Area Title: Plasma Spray Coating

Location: S&P Coatings Inc., Anytown, USA

Date of Analysis: 06-12-07

Job Step or Task		Potential Hazard	Required PPE or Procedure
Hopper Cleaning	Eyes:	Nuisance Dust	Safety glasses
	Lungs:	Nuisance Dust	Respirator
	Hands:	Nuisance Dust	Latex/Nitrile Gloves
Plasma Spray	Eyes:	Bright Light and Bright UV	Face Shield w/ 10-12 Shade Lens
	Lungs	Respirable Dust and Fumes	Respirator
	Skin:	Bright Light and Bright UV	Leather apron
	Hands:	Thermal Burns / Bright UV	Leather gloves
	Hearing:	Noise above 80db	Ear plugs or muffs

Special Instructions (example)

Spray operators and Spray Process Monitors shall use an integrated system of hearing protection:Ear plugs of suitable NRR Rating as well as ear muffs of suitable NRR Rating due the extremely high occupational noise exposure hazards associated with metal spraying processes.

Approvals

Environment, Health & Safety: _____ Date: _____

Department Manager: _____ Date: _____

Department Supervisor: _____ Date: _____

17.4 Appendix D: Filter Lenses for Protection Against Radiant Energy

Minimum(*) Operations

Electrode Size 1/32 in.	Arc Current	Protective Shade
Shielded metal arc welding		
Less than 3	Less than 60	7
3-5	60-160	8
5-8	160-250	10
More than 8	250-550	11
Gas metal arc welding and flux cored arc welding		
	less than 60	7
	60-160	10
	160-250	10
	250-500	10
Gas Tungsten arc welding		
	less than 50	8
	50-150	8
	150-500	10
Air carbon Arc cutting		
(Light)	less than 500	10
(Heavy)	500-1000	11
Plasma arc welding		
	less than 20	6
	20-100	8
	100-400	10
	400-800	11
Plasma arc cutting		
(light)(**)	less than 300	8
(medium)(**)	300-400	9
(heavy)(**)	400-800	10
Torch brazing		3
Torch soldering		2
Carbon arc welding		14
Gas Welding:		
Light (Under 1/8)	Under 3.2	4
Medium (1/8 to ½)	3.2 to 12.7	5
Heavy (Over ½)	Over 12.7	6
Oxygen cutting:		
Light (Under 1)	Under 25	3
Medium (1 to 6)	25 to 150	4
Heavy (Over 6)	Over 150	5

(*) As a rule of thumb, start with a shade that is too dark to see the weld zone. Then use a lighter shade which gives sufficient view of the weld zone without going below the minimum. In oxy-fuel gas welding or cutting where the torch produces a high yellow light, it is desirable to use a filter lens that absorbs the yellow or sodium line in the visible light of the (spectrum) operation.

(**) These values apply where the actual arc is clearly seen. Experience has shown that lighter filters may be used when the arc is hidden by the work piece.