Welding Health and Safety

- This training material has been prepared by 3M for the purpose of helping you understand applicable OSHA standards, or other safety regulations, workplace hazards, and safe workplace practices.

- It is the responsibility of both the employer and employees to comply with safety rules and regulations and to use all safety equipment in accordance with product user instructions, limitations, and warnings. Questions regarding proper use should be directed to the employer or the equipment manufacturer. For 3M products call 3M Technical Service 1-800-243-4630.

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Presentation Overview

- Regulation & Standards Summary
- Respiratory Hazards
- Engineering Controls
- Respiratory Protection
- Arc Radiation Hazards
- Safety Benefits of Auto-Darkening Filters
- Noise Hazards
- Heat Stress Hazards
- Eye & Face Impacts
Common Health Hazards Faced by Welders

- Inhalation of Contaminants
- Arc Radiation
- Noise
- Heat Stress
- Eye & Face Impacts
- Repetitive Stress Injuries
- Electrocution
- Fire
- Compressed Gas
Welding Regulations for USA

Workplace Regulations:
- OSHA 1910 Subpart Q – Welding Cutting and Brazing
- OSHA 1926 Subpart J – Welding and Cutting
- OSHA 1915.51 – Occ. Safety & Health Standards for Shipyards
- MSHA 75.1106 – Welding, cutting, or soldering with arc or flame underground

Performance Standards:
- ANSI Z87.1-2003 – Occupational & Educational Personal Eye & Face Protection Devices (welding shield compliance required by OSHA)
- ANSI Z49.1-2005 – Safety in Welding, Cutting and Allied Processes (available free at: www.aws.org)
Employer Payment For Personal Protective Equipment (PPE) Rule

- Requirement of OSHA’s PPE Standard 29 CFR 1910.132
- Requires employers to pay for required PPE
- Includes most PPE (welding helmets, respirators, leathers, gloves)

- Excluded PPE:
  - Ordinary prescription safety eyewear
  - Non-specialty safety-toe protective footwear
  - Clothing for protection from routine weather conditions (coats, gloves, raincoats, sunglasses and sunscreen)
  - Replacement PPE lost or intentionally damaged by employees

- Employers may allow use of employee-owned PPE, but are not required to reimburse employees
Some Common Respiratory Hazards Associated with Welding

PARTICLES
- Aluminium
- Beryllium
- Cadmium
- Copper
- Hexavalent chromium
- Iron oxide
- Lead
- Manganese
- Magnesium
- Nickel
- Silicon dioxide
- Vanadium oxide
- Zinc

GASES/VAPORS
- Argon
- Carbon dioxide
- Carbon monoxide
- Fluorides
- Helium
- Hydrogen chloride
- Hydrogen fluoride
- Hydrogen sulfide
- Nitrogen dioxide
- Nitrogen oxide
- Ozone
- Phosphine/Phosgene
- Sulphur dioxide
Contaminants Generated By

Welding Fume Generation

Grinding and Polishing

Arc Radiation and Chemical Interactions
Factors Effecting Respiratory Exposures in Welding

- Type of Welding
  - Electrode and Base metals
  - Flux vs. Shielding gas
- Work Position
- Ventilation (area/local)
- Voltage/Amperage
- Coatings on Metal
What is a Welding Fume?

- Welding fumes are **particles** generated by the vaporization of metal near the arc.
- Sources include welding rods (primary), base metal and coatings.
- Metal vapors quickly condense, oxidize and form feathery aggregate particles (not a gas or vapor!)
- NIOSH approved respirators with particle filters can efficiently filter these welding fume particles.

Source: Japuntich, Journal of the Intl. Soc. For Respiratory Prot. 1/84
Welding Fume is Not a Vapor

Welding fume is composed of particles, so welding respirators should always include particle filtration. Vapor filtration may be required in some cases.

This is vapor, not a fume! Vapor cartridges will not filter welding fumes.
What is an Exposure?

- **Exposure Depends On:**
  - Concentration of contaminants in the breathing zone
  - Exposure time
    - Number of minutes/hours a person is exposed

- **Exposure Limits**
  - PEL - Permissible Exposure Limit
    - Established by OSHA – enforced by regulation
  - TLV - Threshold Limit Values
    - Established by ACGIH as guidance (see ACGIH.org)
Some Respiratory Health Effects Linked to Welding Contaminants

- Irritation of the respiratory tract
- Metal Fume Fever
- Siderosis
- Systemic Toxicity
- Manganism
- Possible Lung Cancer

Source: Antonini, Critical Reviews in Toxicology - 33(1), 2003
Metal Fume Fever

- A set of flu-like symptoms that may be experienced following exposure to metal fumes. Symptoms may include:
  - Sweating, shivering, throat irritation, fatigue etc.
- Metals that may cause fume fever include:
  - Zinc (from galvanized metal), cadmium, copper and magnesium
- The on-set of symptoms is typically several hours after leaving work, subside after 24 to 48 hours
- No lasting health effects observed

Source: Antonini, Critical Reviews in Toxicology - 33(1), 2003
Siderosis (Welder’s Lung)

- A lung condition caused by long term over exposure to iron fume
- Usually benign but can rarely lead to pulmonary fibrosis following very high exposures

Source: Antonini, Critical Reviews in Toxicology - 33(1), 2003
Manganism

- Manganese is a metal used in steel to help promote hardness
- Over exposure to manganese may lead to Parkinson’s-like symptoms that may include:
  - Weakness / lethargy
  - Speech disturbances
  - Paralysis (mask-like face, tremors)
  - Psychological disturbance
- The health effects of exposure to manganese as a component of welding fume is currently under debate.

Source: Antonini, Critical Reviews in Toxicology - 33(1), 2003
Manganese is Found in Virtually all Steel Welding Electrodes and Wire

ACME

MATERIAL SAFETY DATA SHEET
For Welding Consumables and Related Products

SECTION I - IDENTIFICATION

Manufacturer/Supplier: ACME
Trade Name: A common wire electrode for steel
Sizes: All
Supersedes: 5/12/99, US-W101A

SECTION II - HAZARDOUS MATERIAL

Important!
This section covers the materials from which this product is manufactured. The fumes and gases produced during welding with the normal use of this product are covered by Section V; see it for industrial hygiene information.
CAS Number shown is representative for the ingredients listed.

1. The term 'hazardous' in 'Hazardous Materials' should be interpreted as a term required and defined in the Hazards Communication Standard and does not necessarily imply the existence of any hazard. All materials are listed on the TSCA inventory.

Ingredients:

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>CAS No.</th>
<th>Wt.%</th>
<th>TLV mg/m³</th>
<th>PEL mg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon steel wire</td>
<td></td>
<td>100</td>
<td>10⁴</td>
<td>10⁴</td>
</tr>
<tr>
<td>Iron</td>
<td>7439-30-6</td>
<td>bal.</td>
<td>10⁴</td>
<td>10⁴</td>
</tr>
</tbody>
</table>

Total manganese

Total copper including plated coating

Manganese and/or manganese alloys and compounds (as Mn)

Limestone and/or calcium carbonate

Quartz
Lung Cancer

- Studies estimate approximately 30 - 40%* increased risk for welders
- Much of this risk is due to high rates of smoking and asbestos exposure among welders
- Suspected link to chromium and nickel exposure from stainless steel
- Possible link to radioactive thorium contained in certain tungsten electrodes used in TIG welding

* Antonini, Critical Reviews in Toxicology - 33(1), 2003
Hexavalent Chromium (Cr\(^{+6}\))

- OSHA standard published Feb 28, 2006 requires effected employers to measure worker exposures to Cr+6 and establish control measures accordingly.
  - OSHA PEL for Cr+6 reduced to 5 µg/m\(^3\) (from 52 µg/m\(^3\))
    - Action level 2.5 µg/m\(^3\) – triggers certain requirements such as medical surveillance
  - By May 31, 2010 – Employers must have engineering controls in place where feasible

- Over exposure to Hexavalent Chromium (Cr\(^{+6}\)) may result in:
  - Lung cancer
  - Irritation or damage to the nose, throat, and lung (respiratory tract)
  - Irritation or damage to the eyes and skin

Source: OSHA, Federal Register: February 28, 2006 (Volume 71, Number 39)
Hexavalent Chromium (Cr\(^+6\))

- Most impacted industries and applications:
  - Electroplating
  - Welding
  - Grinding
  - Painting
  - Producers of chromates
  - Paint and coating production
  - Wood preserving
  - Chromium metal production
  - Steel mills
  - Iron foundries
  - Steel foundries
  - Construction using Portland Cement

Source: OSHA, Federal Register: February 28, 2006 (Volume 71, Number 39)
What Types of Welding Produce Cr\(^{+6}\)?

- Welding processes using flux shielding produce a higher ratio of Cr\(^{+6}\) to Cr\(^{+3}\) than methods using inert shielding gas
  - Flux-Core & Stick (SMAW): 47-62% of total Cr in fume is Cr\(^{+6}\)
  - MIG/TIG: 4% of total Cr in fume is Cr\(^{+6}\)

Source: Larry Verdier et al, Shaw Environmental, AIHCE Expo, 2005
Thoriated Tungsten Electrodes

- Thorium emits alpha radiation
- No risk from skin contact
- Inhalation of particles increases risk of cancers of the lung, bone and pancreas
- Potential exposure from inhalation of particles while grinding
Shielding and Fuel Gas Effects

**Shielding:**
- Argon
- Carbon Dioxide
- Helium

**Fuel:**
- Acetylene
- Propane
- Butane

- Primary hazard is displacement of available oxygen (simple asphyxiants) when welding in confined spaces
- Carbon Dioxide ($\text{CO}_2$) can cause narcosis at high concentrations - headache, dizziness, nausea, drunkenness
Hazardous Byproduct Gas Effects

- **Fluorides**
  - From fluxes and electrode coatings
  - Irritation of eyes, nose and throat

- **Carbon Monoxide**
  - From arc UV light interaction with carbon dioxide
  - Binds to blood preventing transport of oxygen in body

- **Ozone**
  - From arc UV light interaction with oxygen in the air
  - Deep lung irritant causing coughing and fluid build up

- **Phosgene**
  - From UV interaction with chlorinated solvents (e.g. metal cleaners like trichloroethylene) vapors
  - Deep lung irritant causing coughing and fluid build up
Hazardous Byproducts from Coated Materials Include

- Polyurethane coatings may generate some hydrogen cyanide and some toluene diisocyanate
- Epoxy resins may generate aldehydes and carbon monoxide
- PVC generates hydrogen chloride
- Other coatings can result in other potentially toxic exposures
Reducing Exposure by Engineering Controls

- Engineering controls must be used to reduce exposure whenever feasible
- May include local exhaust ventilation (fume extraction), area ventilation, material substitution and process automation
- When impractical to implement or insufficient to control exposure, respiratory protection can be used
Local Exhaust Ventilation

- OSHA 1910.252(c)(3)(i) contains requirements on local exhaust ventilation
- May be impractical to implement in difficult access situations
- Requires welder to frequently move duct
- May disrupt shielding gasses resulting in poor weld quality
Respirator Types

- **Negative Pressure**
  - Wearer breathes through cartridges and/or filters that filter the air

- **Powered and Supplied Air**
  - Clean air is delivered to the facepiece via:
    - Motor/blower drawing air through cartridges/filters
    - Compressed air source
Assigned Protection Factor (APF)

- Each type of respirator has an Assigned Protection Factor (APF) that is assigned by OSHA.
- The APF is the level of protection a class of respirator is expected to provide when selected and used properly under real-world conditions.
- To determine the maximum concentration of a substance in which a respirator can be used, multiply the respirator’s APF by the exposure limit for the substance. For example:
  - Respirator: disposable 1/2 facepiece, APF = 10
  - Exposure: Hexavalent chromium (Cr+3) welding fume, PEL = 5 µg/m3
  - Maximum use concentration for above scenario: 10 x 5 µg/m3 = 50 µg/m3
Facial Hair

- Will cause leakage at the facepiece-to-face seal (even beard stubble)
- OSHA States:
  - "No facial hair that comes between the sealing surface of the facepiece and the face or that interferes with valve function"
- Hoods and loose-fitting headgear can accommodate limited facial hair including beards as long as they don’t violate the above OSHA requirement.
## Negative-Pressure Respirators for Welding Applications

<table>
<thead>
<tr>
<th>Description</th>
<th>APF</th>
<th>No maintenance</th>
<th>Not compatible with facial hair</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disposable Half Facepiece</td>
<td>10</td>
<td>Low cost</td>
<td>Fit-test required</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fits under most welding helmets</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Light weight</td>
<td></td>
</tr>
<tr>
<td>Elastomeric Half Facepiece</td>
<td>10</td>
<td>Replaceable filters</td>
<td>Not compatible with facial hair</td>
</tr>
<tr>
<td></td>
<td></td>
<td>More filter options</td>
<td>May not fit all welding helmets</td>
</tr>
<tr>
<td></td>
<td></td>
<td>More size options</td>
<td>Fit-Test required</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moderate cost</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Light weight</td>
<td></td>
</tr>
</tbody>
</table>
# Positive-Pressure Respirators for Welding Applications

<table>
<thead>
<tr>
<th>Description</th>
<th>APF</th>
<th>Benefits</th>
<th>Drawbacks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Powered-Air (Loose-Fitting or Helmet)</strong></td>
<td>25 or 1000*</td>
<td>Cooling effect</td>
<td>Increased weight</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No breathing resistance</td>
<td>Higher unit cost</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No fit testing</td>
<td>Increased maintenance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hard Hat options</td>
<td>Increased user training</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Accommodates limited facial hair</td>
<td></td>
</tr>
</tbody>
</table>

*Check respirator specifications. Depending on manufacturer’s test results, APF may be 1,000 or 25. |

<table>
<thead>
<tr>
<th><strong>Supplied-Air (Loose-Fitting or Helmet)</strong></th>
<th>25 or 1000*</th>
<th>Chilled or heated air</th>
<th>Attachment to airline</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No breathing resistance</td>
<td>Increased weight</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No filters to change</td>
<td>Higher cost</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No batteries to charge</td>
<td>Requires compressor</td>
</tr>
</tbody>
</table>
N-95 Class ½ facepiece respirators can help reduce exposure to welding fumes from steel, galvanized steel, stainless steel (CrVI) and aluminum where exposures are less than 10 times the exposure limit.

- OSHA substance-specific standards for lead and cadmium require 100 class filters when air purifying respirators are used.
Arc Radiation Hazards

- Arc radiation covers a wider frequency range than sunlight
Overexposure to Arc Radiation

**Potential Symptoms**

- **Ultraviolet**
  - Itchy, Tearing
  - "Sand in the Eyes"

- **Visible**
  - "Fire Ball" Spot Blindness
  - Blood Shot
  - Headache

- **Infrared**
  - Dry, Tearing, Itchy, Headache

**Potential Damage**

- **Ultraviolet**
  - Can happen in milliseconds
  - Usually to cornea (often temporary)

- **Visible**
  - Can take time to happen
    - Seconds to hours
  - Damage can be immediate or accumulative
  - Usually to macular and retina (always permanent)

- **Infrared**
  - Takes long time to happen - usually years
  - Damage is accumulative
  - Usually to the lens of the eye (cataract)
Photokeratoconjunctivitis (Arc Eye)

• Also known as flash burn or welder’s flash

Potential Symptoms
• Inflammation of the cornea
• No immediate pain or sensations during exposure
• Symptoms develop several hours after exposure and last up to two days
• Feels like sand in the eyes
Potential Safety Benefits of Auto-Darkening Welding Filters

- Uninterrupted view of work, during and between welds helmet is down more consistently
  - Reduced probability of impact injuries
  - Reduced arc-eye burns
  - Reduced neck strain from “nodding”

- Secondary benefits include:
  - Increased welder productivity
  - More accurate welds
  - Less time to train welders
  - Less scrap and rework
Auto Darkening Filter (ADF) Construction
ADF Construction

UV/IR band-pass filter (mirror)  Polarizing filter  LC-cell  Polarizing filter  LC-cell  Polarizing filter
Band-Pass Filter

- Protects from IR and UV light
- Allows only visible light to pass through
- Always working – not part of electrical circuitry or switching part of filter
Liquid Crystal / Polarizing Filter

- Work together as an electronic “shutter”
- Only acting on visible light passing through the band-pass filter
- Failure of this filter element to turn dark does not result in eye injury such as arc-eye (see band-pass filter)
ANSI Z49.1 Shade Recommendations

<table>
<thead>
<tr>
<th>Welding Process</th>
<th>Arc Current (Amperes)</th>
<th>Minimum Protective Shade</th>
<th>Suggested Protective Shade (Comfort)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shielded Metal Arc Welding (SMAW)</td>
<td>Less than 60</td>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>60 to 160</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>160 to 250</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>250 to 550</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>Gas Metal Arc Welding (GMAW)(MIG)</td>
<td>Less than 60</td>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>60 to 160</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>160 to 250</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>250 to 550</td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>Gas Tungsten Arc Welding (GTAW)(TIG)</td>
<td>Less than 50</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>50 to 150</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>150 to 500</td>
<td>10</td>
<td>14</td>
</tr>
</tbody>
</table>

- Dependent on welding process and amperage
- Varies according to individual and viewing distance
Auto Darkening Welding Helmets

• Check for compliance to ANSI Z87.1 standard
• Wide range in initial investment cost based on quality and features ($75-500)
• Improves quality and productivity, allows the user to keep the welding helmet down during electrode placement (up to 25-40% productivity increase)
• Improves comfort, reduces neck strain of continuous nodding, especially over time
• Potentially reduces eye injuries due to helmet often being “down” more frequently
Auto Darkening Welding Helmets – Specialty Features

- Sidewindow versions available for increased peripheral vision and safety
- Ventilated helmets to help decrease heat and humidity buildup and fogging of ADF
- Flip-up models available for clear viewing for chipping, grinding and weld prep
- Extended coverage options available for more coverage from UV, spark and spatter
- Some models available with powered and supplied air respiratory protection
Eye and Face Protection

- Welding helmets are required to meet ANSI Z87.1-2003
  - Specifies testing requirements for welding shade filters and helmets
  - Requires use of safety spectacles in conjunction with all welding helmets
- ANSI approved welding helmets and filters required by OSHA (USA)
American National Standard for Occupational and Educational Eye and Face Protection Devices
ANSI Z87.1-2003

• Establishes **performance** criteria and **testing requirements** for devices used to help **protect** against **eye and face** injuries due to **impact, non-ionizing radiation** (e.g. UV) and chemical exposures in workplaces and schools.

• Covers **all** types of protective devices, including:
  – Spectacles (safety glasses)
  – Goggles
  – Faceshields
  – Welding helmets and handshields
  – Full facepiece respirators
Potential Sources of Hazardous Levels of Noise

Noise generated by pulsed/high current welding processes:
- Carbon arc welding and gouging
- TIG (pulsed)
- Plasma

Noise generated by associated activities:
- Grinding & sanding
- Generators
Heat Stress

- Factors that contribute to heat stress:
  - Proximity to radiant heat sources (e.g., arcs, pre-heated metal, grinding swarf)
  - Use of protective clothing (leathers)
  - Ambient temperature
  - Humidity
  - Work rate
  - Hydration
  - Acclimatization
Potential Impact of Safety Equipment on Productivity

- **Reduced**
  - Injuries
    - Eye
    - Repetitive Stress
    - Noise Induced Hearing Loss
    - Heat stress
  - Turnover / Re-training

- **Improved**
  - Morale
  - Quality of work
Welding Health and Safety Topics

Thank you!