Oil & Gas
Safety and Health
CONFERENCE
2018 OSHA®
Exploration & Production

Manganese Exposures during Welding and Hot Work Tasks

Kit Penniall, M.S., CIH

Pauline Rotich, M.S., CIH

William Brown, M.S., CSP

Agenda

- Manganese (Mn) Overview:
  - Uses and general background info
  - Mn exposure limits – historical overview
- Occupational Exposure Limit (OEL) Process:
  - Value of OEL's
  - OEL Process
  - ACGIH basis for recent Mn OEL
- Implementation Strategy:
  - Work activities with exposure > OEL
  - Changes to existing work controls
  - Communications to management and field supervision
  - Welder engagement
  - Future plans

Manganese (Mn) - Overview

- Manganese (Mn) is a naturally occurring element found in geological deposits and in foods including nuts, legumes, seeds, tea, whole grains, and leafy green vegetables

- Benefits:
  - Manganese is an essential nutrient involved in many chemical processes in the body
  - Manganese is used as a medicine for osteoporosis, osteoarthritis, anemia, weight loss, chronic obstructive pulmonary disease (COPD), and other medical conditions

- General population
  - dietary intake of meats, nuts, grains, tea
  - inhalation of ambient Mn constitutes a secondary exposure route (e.g. welding emissions)
  - dermal exposure is negligible (Mn has poor skin penetration)

- Potential Danger:
  - Neurotoxicity of Mn recognized in 1837
  - Recent studies have seen neurotoxic effects in welders

Manganese (Mn) - Overview

Industial Uses

- 90% of mined Manganese is used in steel production to increase hardness and tensile strength
- Steels usually contain at least 0.30% manganese but amounts of up to 1.5% can be found in some carbon steels
- Welding rods contain varying amount of Mn

Where can we find Manganese workplace exposure potential:

- Welding / Hot Work
- Abrasive blasting

exposure via inhalation

3. COMPOSITION / INFORMATION ON INGREDIENTS

Reportable Hazardous Ingredients
Mixtures

Lincoln 7014 Electrode

Chemical Identity	CAS number	Content in percent (%)*
Iron	7439-89-6	>60%
Titanium dioxide	13463-67-7	10 - <30%
Manganese	7439-96-5	<10%
Limestone	1317-65-3	<10%
Potassium silicate	1312-76-1	<10%
Cellulose, pulp	65996-61-4	<10%
Bentonite	1302-78-9	<10%
Sodium silicate	1344-09-8	<10%
Kaolin	1332-58-7	<1%
Bauxite	1318-16-7	<1%
Mica	12001-26-2	<1%
Iron oxide	1309-37-1	<1%
Feldspar	68476-25-5	<1%
Potassium carbonate	584-08-7	<1%
Quartz	14808-60-7	<1%
Carboxymethyl cellulose, sodium salt	9004-32-4	<1%
Aluminum oxide	1344-28-1	<1%

* All concentrations are percent by weight unless ingredient is a gas. Gas concentrations are in percent by volume.

Welding and Manganese Exposure

- Manganese fumes are produced during metallurgical operations and several types of welding operations
  - The exposure can vary considerably depending on the amount of manganese in the welding wire, rods, flux and base metal
- Confined & enclosed spaces can significantly increase exposure to manganese fumes

Background: ACGIH NIC Manganese

- Previous TLV – 0.20 mg/m^3 (adopted in 1995)

- 2010 ACGIH released a notice of intended change (NIC) for Manganese, elemental and inorganic compounds, 8 hour TLV-TWA

- 2011 ACGIH issued revised NIC
  - 0.10 mg/m^3, inhalable particulate
  - 0.02 mg/m^3, respirable particulate
  - recommended to “reduce the potential for preclinical, adverse, neurophysiological and neuropsychological effects in manganese exposed workers”
  - ACGIH changes notable for:
    - 2 to 10-fold reduction from current TLV
    - distinguishes between respirable and inhalable particulate matter

- Key Industry activity is welding operations
  - manganese is present in most welding fumes and dust
  - welder cohorts were not included in research on manganese until the 1980s
    + 1980s to present characterized by shift in focus to welders

Occupational Exposure Limits (OELs)

Airborne concentrations that nearly all workers may be repeatedly exposed to over a working lifetime without adverse health effect

Regulatory

- Country managed

Company OELs

- Occupational Exposure Limit Committee
- Toxicology, Epidemiology, Industrial Hygiene

Corporate Exposure Limits

ACGIH TLV

- Threshold Limit Value
- American Conference of Governmental Industrial Hygienists
- established 1946

WEEL

- Workplace Environmental Exposure Limit
- Toxicology Excellence in Risk Assessment (TERA)

Exposure Time Limits

TWA — Time Weighted Average

8 hours

STEL — Short-term Exposure Limit

15 minutes

Ceiling — Level that should not be exceeded

Value of a Corporate Occupational Exposure Limits (OELs) Process

- Provides a science based position for what is "safe"

- Supports Corporate Health Policy:
  - identify and evaluate health risks
  - apply responsible standards
  - communicate knowledge about health risks

- Supports inputs to emerging and existing regulations (e.g. PELs, BOELs, SDS)
  - Key preventive safeguard for high potential health outcomes

Hazard Characterization

- Mn in welding fumes is predominately respirable
  - majority of inhaled Mn particles will deposit in the alveolar region
  - respirable Mn particulate is the most toxicologically relevant for setting an OEL
- critical / most sensitive effects of Mn exposure are neurological
  - recognized as neurotoxic in the early 1800's (Couper, 1837)
  - high-level (> 5 mg/m^3) and/or long-term chronic exposures are associated with irreversible neuromotor and neuropsychological alterations called Manganism
- other potential health effects of occupational Mn exposure
  - respiratory, cardiovascular, immunological, developmental, reproductive
  - current evidence suggests adverse effects unlikely at levels that begin to affect the CNS but this is a continued subject of research
- data on cancer endpoints are too limited to draw conclusions
  - 'Group D' IARC classification: "not classifiable as to human carcinogenicity"

Fate of Inhaled Manganese: site deposition

Potential health impacts dependent on sites of deposition in the respiratory tract

- nasal passages of the upper airway
  - may reach the brain directly via olfactory transport, bypassing the blood-brain barrier
  - Mn is conveyed along the olfactory nerve, accumulating in the olfactory bulb

- tracheo-bronchial region
  - short half-life (hours) due to clearance by the mucocilliary escalator into the pharynx
  - Mn is swallowed, detoxified and eliminated via the gastrointestinal (GI) tract
  - GI absorption is tightly regulated by homeostatic mechanisms to maintain stable concentrations

- alveolar region
  - particles can be retained for an extended period (700 days)
  - some particles will enter the bloodstream (highly dependent on in vivo solubility of the metal)
  - dissociated metals can be directly transported to the brain bypassing hepatic clearance
    - Mn and Fe compete for circulatory receptor sites and uptake mechanisms

OELs, Recommendations and BMD Analyses for Mn

	source & date	neurologic endpoint	standard R=respirable; I=inspirable; T=total
Proposed	**ACGIH NIC, 2011***	**hand tremor**	**(R) 0.02 mg/m^3 (I) 0.10 mg/m^3**
	German MAK, (?)	motor functions	(R) 0.02 mg/m^3 (I) 0.20 mg/m^3
Established	SCOEL, 2011 **	not specified	(R) 0.05 mg/m^3 (I) 0.20 mg/m^3
BMC/BMD analyses+	Health Canada, 2010	fine motor, cognition	(T) 0.03– 0.06 mg/m^3
	EPA, 1994	hand-eye coordination	(R) 0.07 mg/m^3
	ATSDR & WHO, 2000	hand-eye coordination	(R) 0.07 mg/m^3
	Park et al. 2006	cognition & behavior	(T) 0.02– 0.05 mg/m^3
	Clewell et al. 2003	reaction time, hand-eye coordination, steadiness	(R) 0.10 – 0.30 mg/m^3

* Key studies: Roels et al. 1992 and Park et al. 2006. Supporting studies: Mergler, 1994; Lucchini, 1999; Bast-Petterson, 2004 & Young, 2005
** Key/supporting studies include Gibbs et al., 1999 & Ellingsen et al., 2008, in addition to the studies used by ACGIH
+ Table reports $BMCL_{10}$ results except for Park et al, 2006; HC used Lucchini, et al. 1999. EPA, ATSDR, WHO, Clewell used Roels et al.,1992

US based Manganese Exposure Limits

	TWA	STEL	Comments
OSHA PEL	5 mg/m^3 (C)	NA	PEL set in 1970, adopted from 1968 TLV
NIOSH REL	1 mg/m^3	3 mg/m^3	Set to "to protect employees from the significant risks of manganese poisoning, lung damage, and pneumonia"
ACGIH TLV	0.1 mg/m^3 (IHL) 0.02 mg/m^3 (Resp.)	NA NA	Adopted 2012 Previous TLV: 0.2 mg/m^3 (TWA), total dust

C = ceiling limit
IHL = Inhalable (median particle size of 100 microns)
Resp. = Respirable (median particle size of 4 microns)

- Resp size particles reaching the alveolar spaces are most dangerous due to increased absorption in blood stream
- Larger the particle – generally less hazardous due to less absorption

Summary of Key Statistics – Welding Study

Respirable	Open Air	Shop with ventilation	Shop without ventilation	Confined Space with ventilation	Confined Space without ventilation
Number of samples (n)	38	26	38	9	no data
Percent above TLV	42.10%	15.4%	31.6%	44.4%	

Inhalable	Open Air	Shop with ventilation	Shop without ventilation	Confined Space with ventilation	Confined Space without ventilation
Number of samples (n)	49	26	38	12	no data
Percent aboveTLV	16.30%	19.2%	18.4%	8.3%	

Shop ventilation = Local exhaust
Confined space with ventilation = 2000 cfm/welder

Implementation Strategy

- Conduct air sampling and understand our exposure potentials
- Explore all mitigating options / feasibility of…
- Educate the welding community
  - *Seek a partnership*
  - *Provide a variety of PPE options for trial use*
  - *Gain their feedback on what works, what doesn't, challenges….*
  - *Understand the challenges & be a resource*
  - *How can we better enable & influence this workgroup to do the right thing*
- Work with our industry partners and seek alignment
- Stand fast & do the right thing.

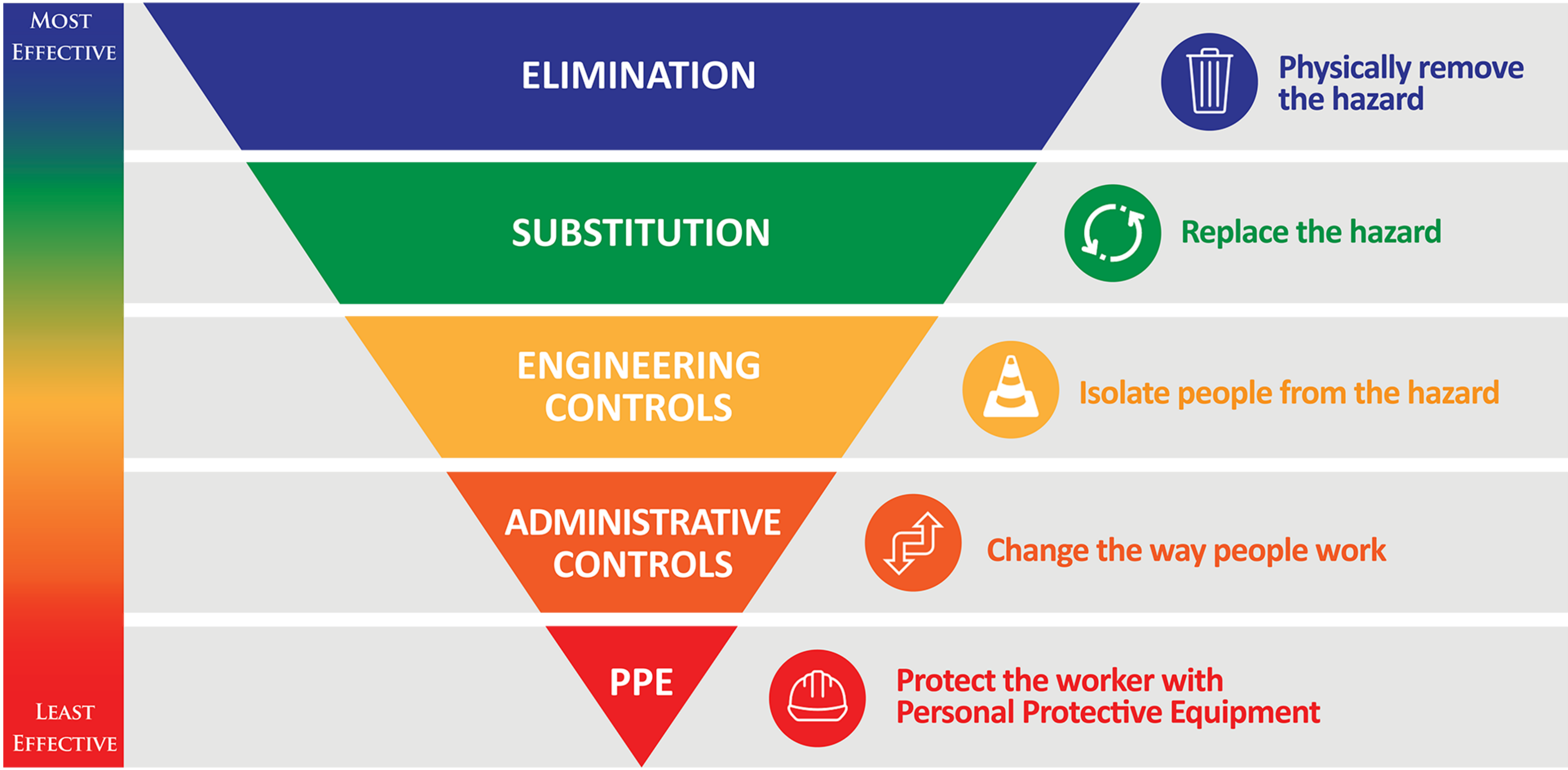
Manganese Exposure Data for Upstream and Midstream

Welding Operations	Total # of Samples	Manganese Inhalable Range (mg/m^3)	Manganese Respirable Range (mg/m^3)	Manganese Inhalable > OEL	Manganese Respirable > OEL
Pipeline	8	0.036-0.30	0.023-0.21	6 (75%)	8 (100%)
Gas Plant	9	0.0018-0.078	0.0094-0.055	0 (0 %)	5 (56%)
Occupational Exposure Limit 8- hour TWA		**0.1 mg/m^3**	**0.02 mg/m^3**	**Total: 6 (35%)**	**Total: 13 (76%)**

- All welding was open air stick welding
- Welders experience ranged from 4-13 years
- Welding jobs included fabrication in plant, pipeline connections, and welding pipe guard for pipeline pig trap.
- Conditions included winds up to 25 mph in West Texas

Welding and Manganese Exposure - Hazards

Hierarchy of Controls



Control Overview

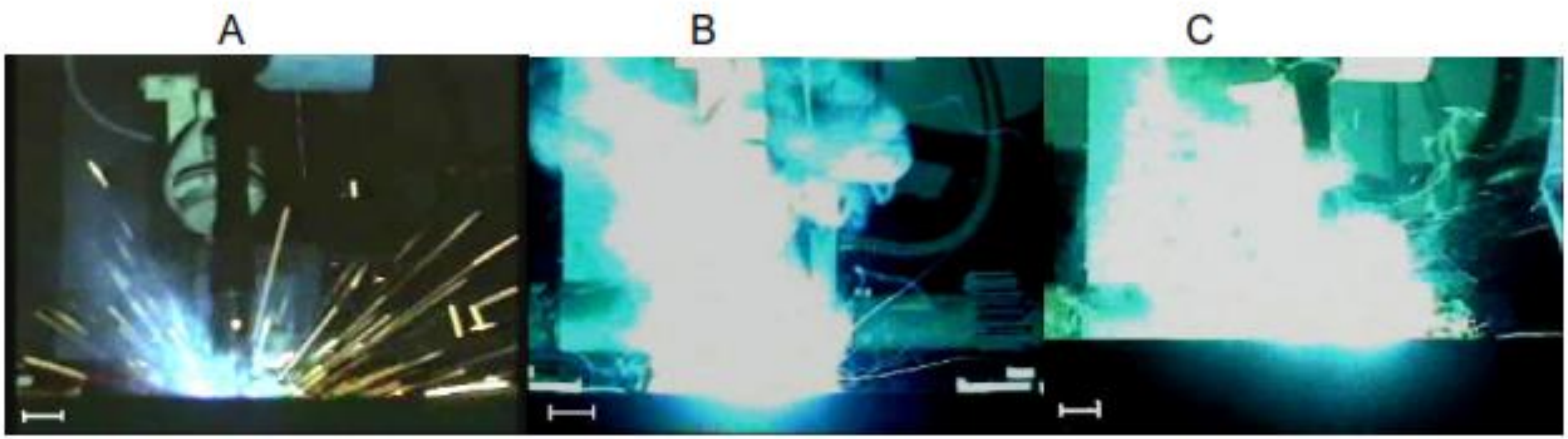
Substitution

- Change type of welding

Administrative

- Electrical current, arc voltage, electrode angle, shielding gas, steady/current pulsed (low fume) current welding

Studies have shown that reducing the voltage of the welding process can significantly reduce the welding fume emissions. The following images show the difference in fume generated by different welding voltages.



Photographs of fume plume in (a) dip transfer (20–26 V); (b) globular transfer (26–29 V); and (c) spray transfer (30–36 V). The scale bar represents ~25 mm

Control Overview

Engineering

- Ventilation
  - Local exhaust ventilation verses general ventilation

Backdraft welding bench is good for welding small parts

Examples of Local Exhaust Ventilation

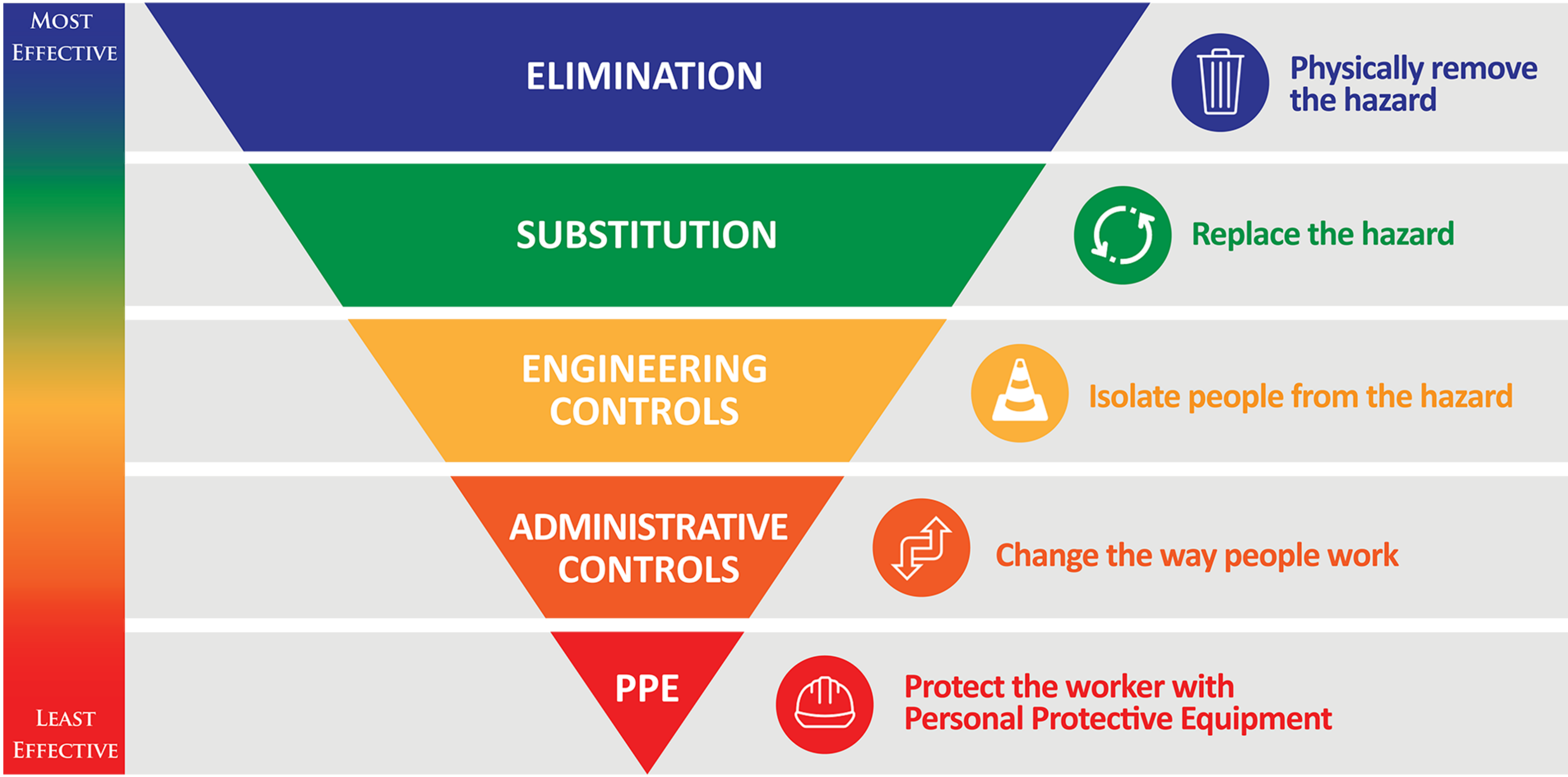
Trunk hose draws the fume away from a welder's breathing zone

Effectiveness of Local Ventilation

Administrative Controls cont.

- Change body positioning and/or rearrange work station so worker is out of the plume
- Challenges with this control method?

Hierarchy of Controls



Respiratory Protection to meet TLV

Welding, Burning, Cutting and Gouging Controls Matrix

Hot Work Process	**Open Area**	**Fabrication Shops or Enclosures**	**Confined Space/Equipment entry[3]**	
			With required MDV of >2000 CFM ($3400m^3/hr$) /welder	**With MDV of <2000 CFM ($3400m^3/hr$) /welder**
All Welding activities (SMAW/TIG/MIG) and Torch cutting	HF	HF or LEV	FF or PAPR	FF or PAPR and LEV or FF SA
Arc Gouging	FF or PAPR	FF or PAPR and LEV or FF SA	FF or PAPR and LEV or FF SA	Requires IH assessment[5]

Choosing the Appropriate Respirator

Before welding in open air, choose the appropriate respirator for your protection

Respirator	Hazard
½ face – P100 (HEPA) *the 'P' means protection from oil mist and dust, mist, fumes  	Welding fumes (manganese) *welding on pipe with residual crude oil that does not contain hydrogen sulfide*
½ face- P100 with Acid Gas cartridge 	Oil mist, Sulfur Dioxide (an acid gas), and welding fumes (manganese) *welding on pipe with residual crude oil that CONTAINS hydrogen sulfide*
½ face- N100 (HEPA) *the 'N' means protection from dust, mist, fumes 	Welding fumes (manganese)

PAPR


Titanium
9400i
Titanium
9400
Hard Hat with
Titanium 9400
Hard Hat with
Titanium 9400i


Speedglas
3M
3M Adflo

Implementation Strategy

- Educate the welding community
  - *Seek a partnership*
  - *Provide a variety of PPE options for trial use*
  - *Gain their feedback on what works, what doesn't, challenges….*
  - *Understand the challenges & be a resource*
  - *How can we better enable & influence this workgroup to do the right thing*

Implementation Strategy

- Engage industry and regulatory partners and seek alignment
- Stand fast & do the right thing

Moral obligation to protect workers