

Best Practices in Industrial Hygiene

A Welding Case Study



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*The **opinions expressed** in this presentation are those of the author.
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Why Welding?

- › 400,000 welders in the U.S.
- › Exposure is widespread and diverse
- › Construction and General Industry in MI
- › Compliance has minimal rules, inadequately protective
- › Most observed welding is non-compliant with health standards, safety compliance comparatively high
- › IARC recently categorized all weld fume as a Group 1 Carcinogen (Lung and Kidney for mild steel welding)
- › We will focus on AREC of weld fume exposures in a general industry setting

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Michigan General Industry Welding Regulations

- Part 301 – Air Contaminants
- Part 380 – Noise
- Part 430 – Hazard Communication
- Part 433 – Personal Protective Equipment
- Part 451 – Respiratory Protection
- Part 520 – Ventilation Control
- Part 529 – Welding, Cutting and Brazing
 - And potentially many more contaminant specific standards

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Part 529 is the problem

- › “Natural ventilation is considered sufficient for welding or cutting operations...
 - In a space of more than 10,000 cubic feet (284 m³) per welder.
 - Having a ceiling height of more than 16 feet (5 m).
 - Without confined spaces or where the welding space does not contain partitions, balconies, or other structural barriers to the extent that they significantly obstruct cross ventilation.

...So long as certain materials are not included in the weld process.

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Anticipation and Recognition of Welding Health Hazards

- › Materials in Use:
 - Metal being joined or cut
 - Filler Metals in use (soldering/brazing)
 - Fluxes in Use
 - Shielding gases
 - Coatings on the metals being joined or cut
 - Cleaning or degreasing solvents

Anticipation and Recognition (cont.)

- › Heat Source for the process
 - Electric arc
 - Electrical resistance
 - Oxyfuel
 - Plasma
 - Laser Beam
 - Electron Beam

Anticipation and Recognition

- › Workplace Environment
 - Open work areas
 - Confined spaces
 - Restricted spaces
 - Wet work areas
 - Multiple welder worksites

4 IH Questions

- › “What are you welding?”
 - Shop shorthand
 - SDS
 - Metal Spec Sheets
- › “What kind of weld process are you using?”
 - Common process hazards
- › “Was the metal coated or cleaned before you weld?”
 - Process residue, paints, polymers, primers, cladding, plating
- › “Where are you going to weld?”

Characterizing the Work Environment

- › How many welders involved in the work? Helpers?
- › Where will the welding take place? Indoor? Outdoor?
- › What other adjacent activities?
- › Is the space confined? Enclosed? Low air dispersion?
- › How large is the workpiece? How many welds are needed where?
- › How are the welders positioned relative to the piece?
 - Welding is somewhat unique, workers must be at arms reach to contaminant source!

Anticipation and Recognition Resources

- › Safety Data Sheets and Spec sheets are primary resource
- › “Effects of Welding on Health”
 - Free at: <https://www.aws.org/standards/page/effects-of-welding-on-health>
- › Documentation of the TLVs
 - Purchase at: <https://www.acgih.org>
- › EU-OSHA Chemical and Material Hazards Database
 - Free at: <https://osha.europa.eu/en/highlights/eu-osha-introduces-new-dangerous-substances-database-check-it-out>
- › CWPR Exposure Control Database (In progress)
<http://ecd.cpwrconstructionsolutions.org/search/hazard-1/work-1/consumable-17/basemetal-1/controlmethod-2/environment-2/>

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Dunnage Welding

- › Many manufacturing facilities use the term dunnage to refer to the containers and packaging used for their finished goods
- › Commonly this packaging is designed specifically to hold the product being manufactured and is proprietary to that manufacturing facilities requirements
- › Also referred to as Material Handling Equipment
- › Mild steel is mainly used for blocking and bracing heavy industrial parts, motors, transmissions and similar products. Large piece work!

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Dunnage Welding

- › Substrate: Carbon Steel
- › Consumable: Carbon Steel welding wire
- › Process: "MIG" – GMAW
- › Coatings: Applied after welding is complete
- › 30 welders per shift, 15 helpers
- › Open Weld Bay: 150' x 100' x 30'
- › Mechanical Dilution Ventilation: 6 Ceiling Mounted VaneAxial Fans (unquantified)
- › Movable weld screens in use
- › Very Loud, adjacent grinding, PIT traffic, compressed air

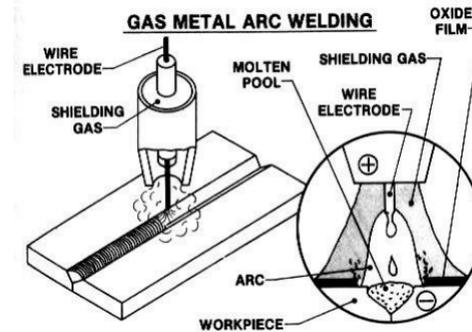
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Gas Metal Arc Welding - GMAW

- › High production welding process
- › Construction/Fabrication
- › Arc between base metal and electrode
- › 9000 F
- › Low mass electrode melts
- › “weld pool”, exclude oxygen



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Factors

- › Most fume generated by electrode
- › Electrode specified by diameter
- › Matched to thickness of substrate metal
- › More diameter, more current, more feed rate, more heat
- › Increasing any of the above increases rate of fume generation (apprentices)
- › Well documented occupational exposures to fume
- › Highly variable exposure based on work position/practices
- › How good can your welders see?

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Fume Constituents

- › Exposure Monitoring
- › SDS for electrode
- › Specification sheet or SDS for base metal
- › SDS for coatings or other process
- › Electrode flux coating primary contributor (90%)
- › For GMAW most common fume is iron oxide, low toxicity
- › Trace Metals: nickel, vanadium, chromium, copper, manganese, or others.

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Metal Fume Fever

- › Caused by Zinc and potentially other metals
- › Flu-like symptoms: cough, dyspnea, fever, chills, chest pain, nausea, and vomiting
- › Recovery without intervention in 24-48 hours
- › Often misidentified

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Manganese

- › Essential ingredient in steel, prevents cracking
- › Present in higher concentrations in welding wire as a deoxidizing agent (Review Rod SDS!)
- › Removes iron oxide from weld pool
- › Highest likelihood of overexposure in GMAW, personal; experience
- › Causes brain damage, Manganism, Parkinson's like symptoms.

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Manganese (cont.)

- › Ceiling of 5 mg/m³
- › No OSHA TWA
- › OSHA Manganese PEL is distinctly non-protective, MIOSHA PEL of 1 mg/m³ as fume better but not enough.
- › TLV 0.02 mg/m³ (250 times less than the OSHA PEL)
- › Average MIG weld exposure around 0.25 mg/m³ (JOEH 2010)

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“Total Weld Fume”

- › IARC Group 1 Carcinogen
- › Particle size of fume is around 1-micron (monodisperse)
- › Smaller particles have higher surface area to volume ratio, more reactive
- › Can potentially penetrate the blood brain barrier
- › MIOSHA PEL (5 mg/m³) was set without reference to Carcinogenicity of fume, and is absurdly high for a known carcinogen
- › Overexposures routinely encountered in dunnage shops

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Hypothetical Case Study

Review of Metal Spec Sheet indicates:

- Chromium – 1% (IARC-1 Carcinogen)
- Manganese – 0.5 % (Fume Fever, Manganism)
- Molybdenum – 0.5% (Low Tox)
- Nickel - 3% (IARC -2B as fume)

Review of Consumable SDS:

- Manganese – 2%
- Molybdenum – 0.25%
- Nickel - 0.25%
- Chromium – 0.25%

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Dunnage Shop Observations

- › Visible haze in welding area and adjacent production areas
- › Noticeable burnt metal odor
- › Visible accumulation of dark, fine, oily dust on horizontal surfaces, fan guards, walls, structural elements
- › Plumes observably rising off weld processes
- › No observable pressure differential to adjacent areas
- › Filtering facepieces available for voluntary use, scattered on floor

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Evaluation

- › “Do we *have* to do air monitoring?”
- › 29 CFR 1910.134(d)(1)(iii)
 - “The employer shall identify and evaluate the respiratory hazards in the workplace; this evaluation shall include a reasonable estimate of employee exposures to respiratory hazard(s) and an identification of the contaminant’s chemical state and physical form. Where the employer cannot identify or reasonably estimate the employee exposure, the employer shall consider the atmosphere to be IDLH”
 - IDLH = supplied air respiratory protection, so you could buy 45 SARs
 - Weld exposures typically covered by APR of 10-50, so air monitoring is actually a cost-effective option

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Contaminants of Concern

- › Total Weld Fume
- › Manganese
- › Nickel?
- › Chromium?
- › Hexavalent Chromium?
- › Paint solvents or decomposition products?

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Sampling and Analysis Methods

- › NIOSH Manual of Analytical Methods (NMAM)
 - Free at: <https://www.cdc.gov/niosh/nmam/default.html>

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Total Weld Fume

- › Gravimetric Method
 - Over and Under-protective
 - Benign contaminants – iron oxide, non-production dusts
 - Does not capture individual or synergistic effects of constituent metals
 - Does not capture vapor/most liquid phase

- So not really Total, not only Weld, and not only Fume.
- Rejected by Fed OSHA, used by MIOSHA (5 mg/m³) and ACGIH
- NIOSH – lowest feasible concentration

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Substance-Specific Methods

- › NIOSH Method 7300
 - Elements by ICP (AAS also available)
 - Chromium, manganese, zinc usually included in panel
- › NIOSH Method 7600
 - Hexavalent Chromium
 - Uses PVC cassette, would require 2 samplers
 - Typically evaluate total chromium and see if additional monitoring required (if no chromium, no hexavalent chromium)
 - GMAW 2/3 of chromium is hexavalent – experience/anecdotal

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Collecting Air Samples

- › NIOSH Methodologies specify personal breathing zone sample using active low-flow pump sampling around 2 LPM
- › MIOSHA sampling specifies “in-hood” sampling, exception to general rule of sampling outside worker PPE
- › Varying professional opinion as to effect of welding hood on airflow patterns around the face and effect on measured concentrations
- › Like most aspects of welding, I believe it varies by manufacturer/PPE, work position remains dominant factor

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Inside Hood Monitoring

- › Causes resistance from welder, distracting
- › Smaller diameter cassettes for gravimetric analysis
- › Cassette holders place cassette in midline of helmet

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Best Practices in Evaluation

- › Due to health effects below PELs, ensure air sampling methodology is as sensitive as possible, down to 100 ug/m³ if possible
- › AAS instead of ICP analysis

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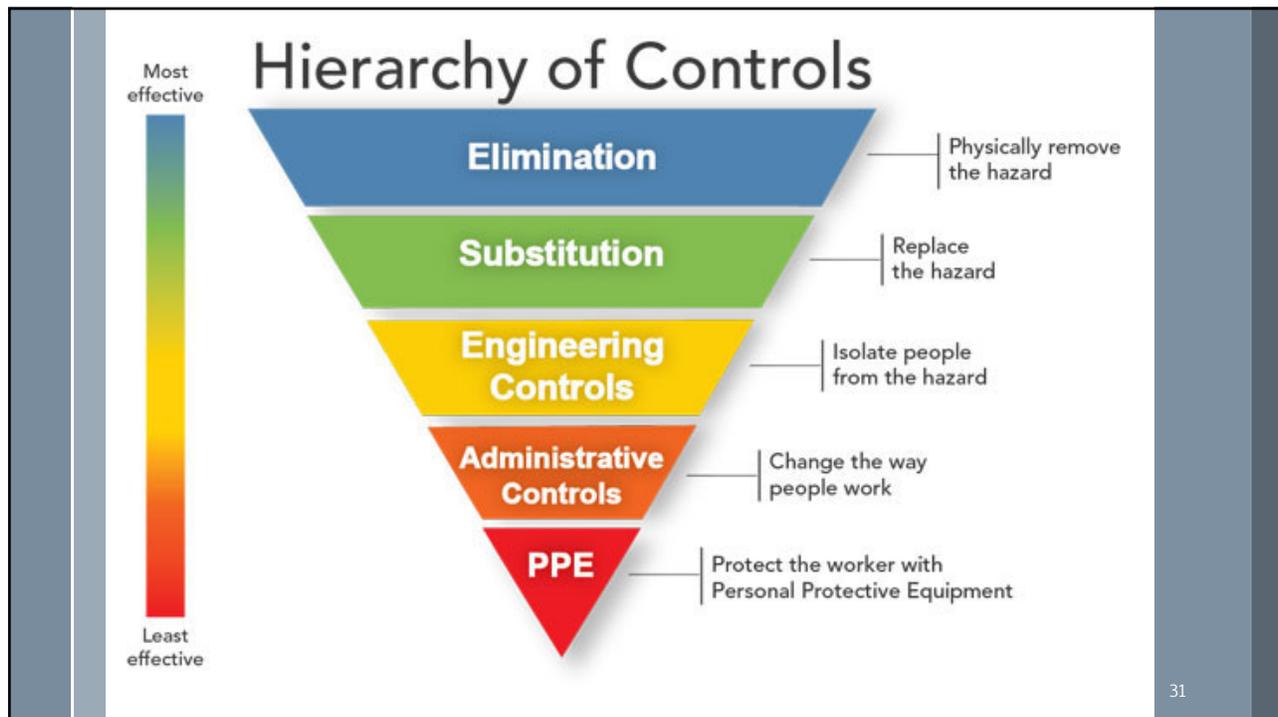
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Best Practices in Evaluation

- › Video Exposure Monitoring
- › Identify peak exposures for reduction
- › Recorded video is matched with information of hazardous particulate levels collected simultaneously, excellent for retraining work practices and communication
- › NIOSH EVADE 2.1 – From MSHA
 - Available free at:
<https://www.cdc.gov/niosh/mining/Works/coversheet1867.html>
 - Crowdsourcing direct reading data, wearable sensors
 - Miniaturization of current lab technology – direct reading accreditation through AIHA LAP?

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Elimination/Substitution

- › Already externalized by automotive manufacturers to dunnage industry, high compliance cost may lead to international supply
- › Robotic welding or isolation of workers difficult
- › Other Weld Process Substitution
 - Stick (SMAW) is dirtiest
 - FCAW may increase fume generation, also spatter hazard on large piece work
 - Mild steel already low toxicity substrate
 - Copper in electrode increases fume, low copper may increase spec metals though
 - GTAW would emit less, but too large of weld needed
 - Covered/coated electrodes bring in fluoride concerns, especially high production

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Substitution (cont.)

- › Decrease Arc voltage/arc length
- › CO₂ as inert gas generates more fume, use Argon mix
- › Changing base metal does not really affect fume generation rate, it slightly affects fume composition
- › Most bang for the buck in electrode substitution
- › Source reduction is best IH practice
- * May require recertification of weld process, retraining of employees, retesting of ventilation

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Problems with Part 529 Continued

- › Mechanical or Local Exhaust required by regulation:
 - If employees overexposed
 - If welding in certain spaces
 - If welding involves:
 - › “zinc-bearing metals”, “metals containing lead other than as an impurity”, “lead-base”, “metals coated with lead bearing materials”, beryllium containing base or filler metals”, cadmium bearing or cadmium coated base metals”, cadmium bearing filler metals”, or “metals coated with mercury bearing materials” and more...
 - › WHAT DO THESE TERMS MEAN? Is our 3% mild steel “zinc-bearing”?

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Engineering Controls

- › Local Exhaust Ventilation
- › LEV “Drops”
- › Portable HEPA filtration devices
 - ACGIH Industrial Ventilation Manual, 29th Edition
 - Available at:
https://www.acgih.org/forms/store/ProductFormPublic/search?action=1&Product_productNumber=2097
- › Fume Extraction Guns – more ergonomic than in the past

Engineering Controls

- › Very well established fume extraction methods
- › There *should be* a change in enforcement
- › Given the recent IARC reclassification, ALL welding, including mild steel welding should be done with engineering controls such as local exhaust ventilation

Administrative Controls

- › Work practices and re-training greatly effective in reducing exposures
- › Body/work piece/ventilation approach
 - keeping his or her head out of the weld plume
 - changing body position so that the airflow moves from back to front
 - making sure any air movement in the work area pushes fume away from the breathing zone.
 - Rotating fixtures excellent for stationary LEV
- › Hazard Communication is key

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Personal Protective Equipment

- › Respiratory Protection against fumes
 - Follows air monitoring to assign correct Assigned Protection Factor (APF)
 - › Half Face Negative Pressure Respirator – APF 10
 - › Powered Air Purifying Respirator – APF 50
 - Requires Written Respiratory Protection Program, Part 451
 - NIOSH approved respirators only
 - Flame Retardant
 - Excellent Weld Helmet/PAPR combination units on the market
 - “Paper Masks” are demonstrably weak protection against weld fume as small particles bypass “nose bridge”
 - Often used as primary control due to need for mobility around large work pieces, should be last resort as they rely on worker

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Dunnage Controls Implementation

- › Include weld fume hazards in Initial and annual employee training
- › Consider low manganese consumable substitution
- › Implement Local Exhaust – LEV drops better than portable units due to:
 - PIT traffic
 - crane usage,
 - stationary large piece work in designated “bays”
 - Usage of weld screens
 - Reduced operating cost compared to Dilution, 64000 cfm vs 88 per drop approximately 12 drops needed)
 - Use Ventilation professionals! No set level from OSHA, use ACGIH guidance
- › Audit results against baseline air concentrations

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The #1 secret

- › The more collaborative the effort, the better the results.

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Thank You For Attending This Presentation

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