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Sheet Metal & HVAC Safety Intervention Adoption & Best Practices Research

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Abstract

Sheet metal and HVAC workers are exposed to welding fumes and nanomaterials, causing health and safety concerns. By measuring the adoption levels of safety interventions, this project quantifies a benchmark of adoption and understanding of existing interventions for mitigating welding health risks. Interviews and targeted surveys with members of the leading professional and trade associations were conducted, and data was collected from businesses with fewer than 10 employees. A comprehensive welding safety measures and interventions list to mitigate fumes and nanomaterials was developed and classified into five categories. Among the items on the list, the study identified those companies were least likely to provide and the welding safety measures with the lowest levels of adoption. A list of the most prevalent reasons for not using safety measures or equipment is provided, in addition to common injuries and preventative measures.

Key Findings

1. A comprehensive list of welding safety measures and interventions was developed based on research, industry interviews, and surveys. It categorizes the safety measures into five areas.
2. Based on a national survey of the Sheet Metal and Air Conditioning Contractors National Association (SMACNA) and the Mechanical Contractors Association of America (MCAA), wet slurry vacuum to remove coatings, laser welders, fume extractor guns, third-party occupational studies of employees' health, and third-party welding fume studies were the least common safety measures provided by companies.
3. Based on the same national survey, point of operation ventilation/welding fume extractors, wet slurry vacuum to remove coatings, and fume hoods have the lowest perceived levels of adoption (as defined by workers not using or not using the intervention properly).
4. Based on the survey, eye injuries and burns were the most common welding injuries sustained within the previous 12 months.
5. Based on the survey, job/task simplicity and personal preference (or physical discomfort) are the reasons most commonly offered for not using welding safety measures.
6. In interviews with welders employed by companies with fewer than 10 employees in the southwestern USA, 57% stated that their company provided general PPE only (such as gloves or protection for the eyes or ears), while 43% stated their company did not provide any safety measures or equipment (welding specific or general PPE). The group of interviewees said these results were probably different from the MCAA and SMACNA survey results because contractors in these professional associations employ union workers who have documented safety requirements. Future research should continue to explore differences among union and non-union welding employers.
7. When comparing the national survey with the southwestern welders' interviews, three common top reasons welders give for not using the safety measures emerged as: convenience/trouble and old habits, job simplicity, and personal comfort. Strategies to increase adoption of safety interventions by welders should address these reasons/reactions.
8. Grinder machine safety is a common concern, as safety protocols with this equipment in related welding operations are commonly not in place (guards removed, wrong size blade for the grinder, etc.).

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Introduction

The provision and adoption of safety practices, protocols, interventions, and control technologies to reduce workers' exposure to fumes and nanomaterials within firms in the sheet metal and HVAC industry has not previously been measured, limiting the industry's ability to reduce or eliminate these hazards. Without clear measurement of the degree to which companies provide the interventions and both individuals and companies adopt personal protective equipment, control technologies, etc., methods for how to effectively increase adoption cannot be developed to reduce exposures. Although much research has focused on measuring the prevalence of the risk of exposure, more is needed on the identification of the providing and adoption levels of intervention measures for sheet metal workers, plumbers, and boilermakers.

A 2014 CPWR study revealed that exposures to man-made mineral fibers (MMMF), cement dusts, drywall dusts, and spray paint, carbon arc welding, and urethane foam insulation, were statistically associated with chronic obstructive pulmonary disease (COPD) risks.¹ The prevalence, mortality, and high costs of COPD highlights the need for more research regarding respiratory protection. While COPD can be caused and exacerbated by a variety of lifestyle factors,² this research is focused on those pertaining to exposure to hazards in the sheet metal and HVAC industry. According to the National Heart Lung and Blood Institute, 16 million Americans have COPD.³ In 2010, more than \$32 billion was spent on COPD-related patient care and was projected to increase to \$49 billion in 2020.⁴

The National Institute for Occupational Safety and Health (NIOSH) has identified a research goal to reduce occupational respiratory disease due to "5.3 mixed exposures," with a focus on exposure to welding fumes and fumes generated by closed in-place pipe operations. NIOSH notes that research aimed at improving the existence, performance, and adoption of control technologies, prevention approaches, and interventions for worker exposures to welding fumes (engineering controls, personal protective equipment, etc.) is needed.⁵

Studies of safety climate, which is an established leading indicator of safety "adoption,"⁶ are a key body of knowledge for this study. A review of the past 30 years of safety climate literature shows that a gap still exists in understanding the antecedents, moderators, mediators, and interrelationships of safety climate with other safety constructs. Other topics in need of further study include employment-level specific subscales of climate perceptions (i.e., supervisor vs. senior management) and industry-specific climate scales. Quick movement from research to practice is a goal for this study and key to advancing the adoption of safety protocols/interventions within the sheet metal and HVAC sector of the construction industry.

The present research is the first of its kind to integrate an interdisciplinary approach to adoption measurement. It incorporates foundational models from the fields of industrial psychology, organizational change/business, and engineering/construction management. To the researchers' knowledge, there has not

¹ Dement, J., Welch, L., and West, G. (2014). Airways Obstruction among Sheet Metal Workers Participating in a Respiratory Screening Program. The Center for Construction Research and Training, Retrieved February 19, 2021, from: <https://www.cpwr.com/wp-content/uploads/publications/DementCOPDAmongSheetMetalWorkers.pdf>

² Earl S. Ford, Louise B. Murphy, Olga Khavjou, Wayne H. Giles, James B. Holt, and Janet B. Croft., (2015) "Total and state-specific medical and absenteeism costs of COPD among adults aged ≥ 18 years in the United States for 2010 and projections through 2020," *Chest*, 147 (1), pp. 31-45.

³ National Heart Lung and Blood Institute (2009) Chronic Obstructive Pulmonary Disease. Retrieved February 19, 2021, from: <http://www.nhlbi.nih.gov/health/public/lung/copd/>

⁴ National Institutes of Health & Center for Disease Control and Prevention. (2020) COPD National Action Plan (2020). Retrieved February 19, 2021, from: <https://www.nhlbi.nih.gov/health-topics/all-publications-and-resources/copd-national-action-plan>

⁵ National Institute for Occupational Safety and Health (n.d.), Research Goals: 5 – Reduce Occupational Respiratory Disease: Constructions, Accessed on February 8, 2021: <https://www.cdc.gov/niosh/about/strategicplan/respons.html>

⁶ Probst, T. M., Goldenhar, L. M., Byrd, J. L., and Betit, E. (2019). The Safety Climate Assessment Tool (S-CAT): A rubric-based approach to measuring construction safety climate. *Journal of Safety Research*, 69, 43-51. <https://doi.org/10.1016/j.jsr.2019.02.004> Zohar, D. (2009). Thirty years of safety climate research: Reflections and future directions. *Accident Analysis and Prevention*, 42, 1517-1522. <https://doi.org/10.1016/j.aap.2009.12.019>

been measurement of both individual (adoption) and company (provision) levels of adoption of safety practices, protocols, interventions, and control technologies to reduce workers' exposure to fumes and nanomaterials by contractors in the sheet metal and HVAC industry.

Existing models from industrial psychology and organizational change were used as inspiration to measure the levels of adoption of a new process, system, tool, etc.^{7,8,9} Further, guidance was taken from measurements in the construction industry regarding new process adoption.¹⁰

Objectives

The objectives of this research were to:

1. Identify and document a comprehensive list of sheet metal and HVAC sector-specific safety interventions (including safety protocols, specialized safety-integrated equipment, Personal Protective Equipment (PPE), and control technologies).
2. Produce quantified employee- and company-level data on adoption of those previously identified safety interventions, including: (1) if interventions were provided by companies and (2) if interventions were used by their employees.
3. Establish a baseline of the safety interventions provided and safety adoption for this sector, allowing comparison and enabling industry-wide measurement of change in levels in the future.

Methods

The following were the methods of this research:

1. Review of existing research and studies
2. Interviews and discussions with safety committee leadership of two premier contractor associations: Mechanical Contractors Association of America (MCAA) and Sheet Metal and Air Conditioning Contractors National Association (SMACNA)
3. Development of a comprehensive list of sheet metal and HVAC sector-specific safety interventions (including safety protocols, specialized safety-integrated equipment, Personal Protective Equipment (PPE), and control technologies) (see Appendix A).
4. Development of a national survey related to welding safety in the sheet metal and HVAC industries
5. Pilot testing the survey and adjust the survey based on feedback
6. Distributing the survey (full survey shown in Appendix B)
7. Analyzing survey responses. Survey demographics are shown in Appendix C.
8. Conducting targeted interviews and discussions with welding professionals (interview questions shown Appendix D)

⁷ Giangreco, A. and Peccei, R. (2005). "The nature and antecedents of middle manager resistance to change: evidence from an Italian context." *International Journal of Human Resource Management*, 16(10), 1812-1829.

⁸ Lines, B. C., Sullivan, K. T., Smithwick, J. B., and Mischung, J. (2015). "Overcoming resistance to change in engineering and construction: Change management factors for owner organizations," *International Journal of Project Management*, Vol. 33(5), pp. 1170-1179. DOI:10.1016/j.ijproman.2015.01.008.

⁹ Giangreco, A. and Peccei, R. (2005). "The nature and antecedents of middle manager resistance to change: evidence from an Italian context." *International Journal of Human Resource Management*, 16(10), 1812-1829.

¹⁰ Aldossari, K., Lines, B., Smithwick, J., Hurtado, K., and Sullivan, K. (2021). "Employee Reactions to Adoption of Alternative Project Delivery Methods within the AEC Industry." *International Journal of Construction Education and Research*.

<https://doi.org/10.1080/15578771.2021.1900463>; Lines, B. C., Sullivan, K. T., Smithwick, J. B., and Mischung, J. (2015). "Overcoming resistance to change in engineering and construction: Change management factors for owner organizations," *International Journal of Project Management*, Vol. 33(5), pp. 1170-1179. DOI:10.1016/j.ijproman.2015.01.008.

Accomplishments And Results

The accomplishments and results of this study are organized as follows:

1. Welding industry adoption considerations
2. Comprehensive Welding Safety Measures list
3. Adoption levels

Welding Industry Adoption Considerations

After reviewing the relevant literature related to safety climate, safety hazards recognition, welding hazards, and others, the researchers developed a variety of ways to assess the adoption levels of welding safety measures. The researchers' ideas were presented to MCAA and SMACNA for review and discussion, including meetings with the SMACNA Safety and Health Committee (an 11+ member board of industry professionals, each with 10 or more years of industry experience).

A number of important ideas emerged from those discussions:

- Levels of “adoption” may be skipping other prerequisite data, as it assumes welders already have the safety gear they need. A more holistic mental model was defined and is presented in Figure #1.
 - There is a large need for understanding what safety measures are not provided by companies, especially smaller companies.
 - Determining if a company’s welders are trained upfront is essential.
 - Knowing why welders may choose not to use what is provided is another important aspect of adoption.
- Due to COVID, perception of being audited, and lack of anonymity, many companies would not be willing to have someone visit their company.
- It would be best to avoid questions that ask for conclusive or absolute numbers or percentages about all employees, as survey respondents would be hesitant to respond, may feel unable to quantify, and/or feel obligated to respond in a positive light (even though the survey is anonymous).
- There may be a potential concern with questions comparing company production goals/objectives vs. safety priority, as they may be taken out of context.

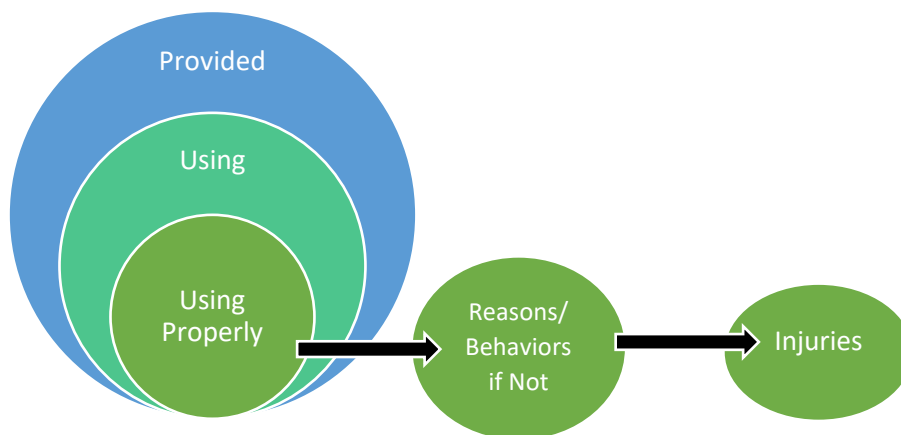


Figure 1 - Adoption Mental Model

Based on these discussions, a series of questions was developed to measure welding safety adoption, from perspective of both the company and employee (the full survey and interview questions are included in Appendices B and D; “*” notes if there is a similar interview question). The areas were:

1. Number of welders*
2. Location of welders
3. Frequency of welding
4. Welding training
5. Reasons for not using welding safety gear*
6. Welding safety gear that’s not provided by the company*
7. Other safety measures used
8. Top welding safety measures not used/not used properly
9. Welding injuries
10. Other methods used to encourage welding safety
11. Value of welding safety
12. Safety structure
13. Demographic questions*

Comprehensive Welding Safety Measures List

After reviewing the relevant literature and welding safety-related resources, such as from ANSI, NASD, and OSHA the researchers developed a preliminary list of welding safety measures. Through interviews and pilot testing, including discussions with welding professionals, 25 welding-specific safety interventions were identified. A comprehensive list of welding safety measures and interventions was developed and is presented in Appendix A. The list categorizes the safety measures into five different areas as follows:

1. General PPE
2. Ventilation equipment
3. Policies/procedures
4. Materials & equipment
5. Other

Adoption Levels

The extent to which the welding-specific safety measures and interventions on the list were not provided by companies and not adopted by workers/welders was then measured via the national survey of MCAA and SMACNA members (more detailed figures and tables are in Appendix C).

Not Provided

Using this list in the survey, respondents selected the measures (within each area) that their company *does not provide*. The results are presented in Table 1 below. The top five (5) least commonly provided measures include:

- 52% of companies do not provide a wet slurry vacuum to remove coatings
- 48% of companies do not provide laser welders
- 35% of companies do not provide fume extractor guns
- 35% of companies do not conduct 3rd party welding fume studies
- 35% of companies do not conduct 3rd party occupational studies of employees’ health

These findings are important because they provide new information and a baseline measure of how frequently companies supply interventions that could mitigate hazards.

Table 1: Comprehensive Welding Safety Measures List (Items that the company *does not provide*)

Area	Welding Safety Items	# of Companies for This Area That Do Not Provide This	% of Companies for This Area That Do Not Provide This	% of Total Companies Do Not Provide This
General PPE (N = 52)	Welding aprons	25	48%	20%
	Welding helmets	13	25%	10%
	Welding jacket	8	15%	6%
	Eye protection	3	6%	2%
	Welding gloves	3	6%	2%
Ventilation Equipment (N = 121)	Fume extractor guns	44	36%	35%
	Vacuum systems	33	27%	27%
	Fume hoods	27	22%	22%
	Point of operation ventilation / welding fume extractors (smoke eaters)	11	9%	9%
	Shop ventilation	6	5%	5%
Policies & Procedures (N = 85)	Ergonomic considerations for welding	23	27%	19%
	Hexavalent Chromium protocols	17	20%	14%
	NIOSH guidelines	16	19%	13%
	ANSI/AWS standards	11	13%	9%
	Published checklist of safety practices to take when welding	9	11%	7%
	Hot work permits	6	7%	5%
	Job hazard analysis	3	4%	2%
Materials & Equipment (N = 131)	OSHA standards	0	0%	0%
	Wet slurry vacuum to remove coatings	64	49%	52%
	Laser welders	59	45%	48%
	Tools and procedures to encourage the removal of coatings before welding, as needed	7	5%	6%
	Offer a variety of welder machines (flux, shielded metal, gas metal, etc.)	1	1%	1%
Other (N = 83)	Flash shields	0	0%	0%
	3 rd -party occupational studies of employees' health (i.e., standard health screening)	43	52%	35%
	Conduct 3 rd -party welding fume studies	40	48%	32%
	Other: PAPRs	0	0%	0%

Lack of Adoption

As discussed in the Welding Industry Adoption Considerations section, targeted questions were developed to appropriately measure adoption levels and gain the maximum response rate to the national survey. To further understand adoption constructs around lack of use, a situation was developed in concert with the pilot testers, involving a survey respondent imagining themselves in the field/shop and recalling the most misused or unused safety measures. From this, an additional survey question set was developed that asked if the respondent were to walk their site/shop right now, which of the safety interventions provided would welders either not be using (reasons measured later) and should be or not using properly. The results are shown in Table 2.

Table 2: Top Safety Measures that Workers Are Not Using or are Not Using Properly

Rank	Welding Safety Measures	Not Used/Not Used Properly
1	Point of operation ventilation/welding fume extractors (smoke eaters)	24%
2	Wet slurry vacuum to remove coatings	24%
3	Fume hoods	13%
4	Welding aprons	12%
5	Hexavalent Chromium protocols	11%
6	Hot work permits	6%
7	Welding jacket	4%
8	Other	3%
9	Welding helmets	2%
10	Welding gloves	1%

To increase companies providing and worker adoption of these safety measures, the workers' reactions and responses to using these safety measures were collected.

Workers' Reactions/Responses

Workers' verbal and nonverbal reactions can identify potential resistance to adoption of the safety measures. During the pilot testing phase, the most common reactions/behaviors were likened to avoidance and refusal. Rather than asking a single-response question, across several interviews with members of the SMACNA Safety Committee, a list of the most common reasons given for not using welding safety measures was developed. Training was measured separately in the survey, with 100% of respondents either requiring training upfront and/or providing it while employed (see Appendix B). The most common reasons for not adopting fell into two main categories: (1) job/task and (2) personal reactions/behaviors. Additionally, an open-response option was available in both categories. From this, the survey was developed and distributed that still included an open-response question.

Job/Task Sub-Reactions/Behaviors

Question 1: The first question identified survey respondents' perceptions of why their company's welders do not use safety measures related to the job/task being performed. Responses included:

1. The job is simple/quick (I'm just tack welding).
2. It is not possible to bring equipment into the space where I'm working.
3. Safety makes me feel rushed to finish the job, safety would take away time from the job, etc.
4. I left my gear back at the tool crib and just wanted to weld a few to get going.
5. I'm going to multiple sites and don't have the time to re-setup safety wear.
6. Other:
 - "I've always done it this way"
 - "There is not enough of the right equipment"
 - "It's a pain in the butt"
 - "Wearing respirator masks are annoying"

The results of the survey are shown in Figure 2 below. The reaction of “the job is simple/quick (I’m just tack welding)” was the most common job-related reason (64% have heard this) as to the feedback heard from welders as to why welders may not always choose to use the safety measures.

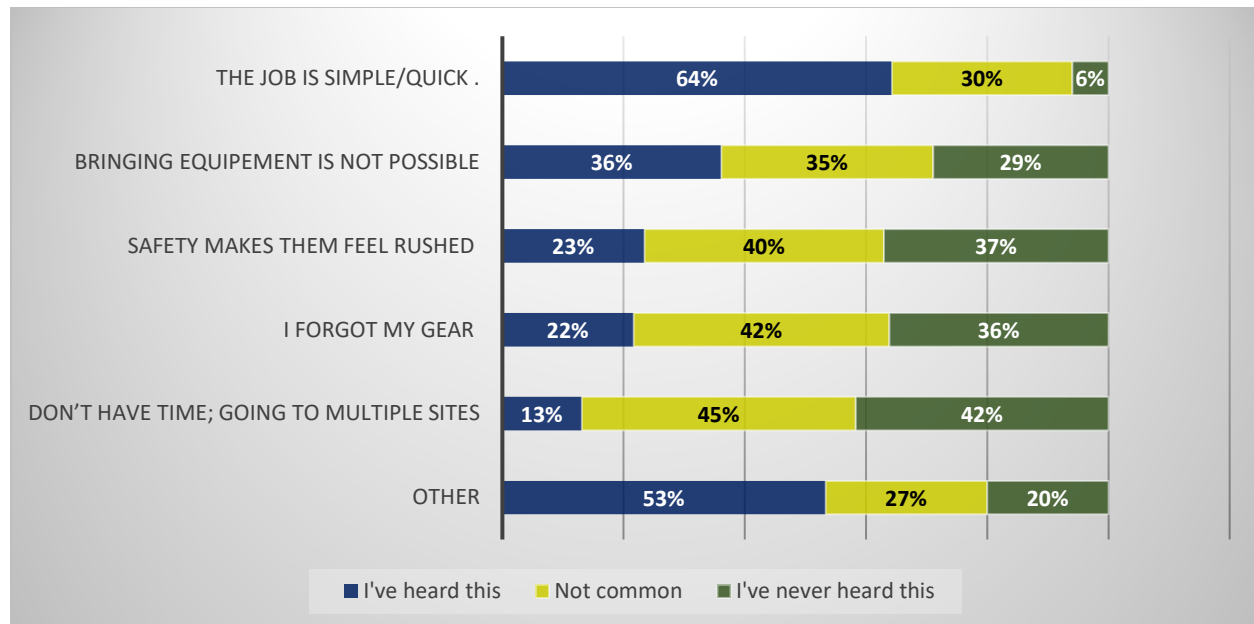


Figure 2: How often you hear welders say the following about why they may not always choose to use safety measures? (job/task reasons).

Personal Sub-Reactions/Behaviors

Question 2: The second question identified personal reasons or reactions. The responses included:

1. Personal preference (I want to use my own gear, this isn't the brand I like, etc.)
2. Physical discomfort (I'm not comfortable using this gear)
3. Been in the industry too long, stuck in their own ways of doing things.
4. “Machoism,” a commonly used phrase for this reason: “real men don't do/use this.”
5. Unsure of how to use it properly and/or have not received adequate training.
6. Physical inability to use (for example, they have a physical impediment that prevents them from being able to wear a mask, decreased lung capacity due to smoking, asthma, previous injury, etc.)
7. Other (many left the text-based portion of the response blank):
 - “It's just too much trouble.”

The results of the survey are shown in Figure 3 below. Personal preference (64%), physical discomfort (63%), and “being stuck in their old ways of doing things” (60%) were closely the most common personal-related reasons.

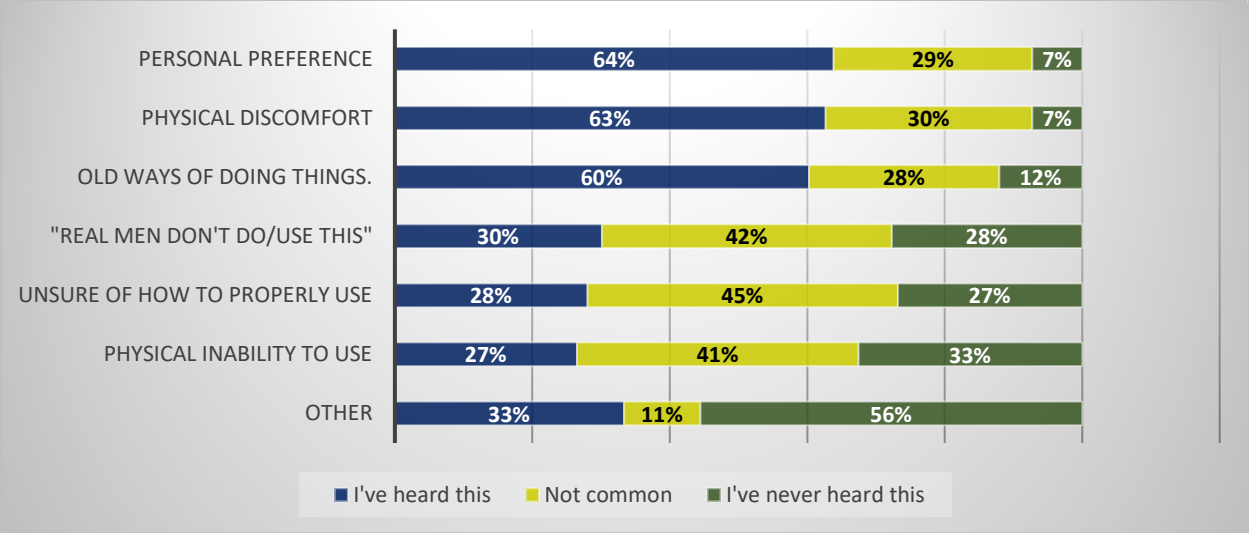


Figure 3: How often you hear welders say the following about why they may not always choose to use safety measures (*personal reasons*).

Injuries and Preventative Measures

To determine the recent types of injuries related to welding, the survey asked what injuries workers have experienced during welding operations in the past 12 months. The most common were eye injuries (28%) and burns (27%) (Figure 4).

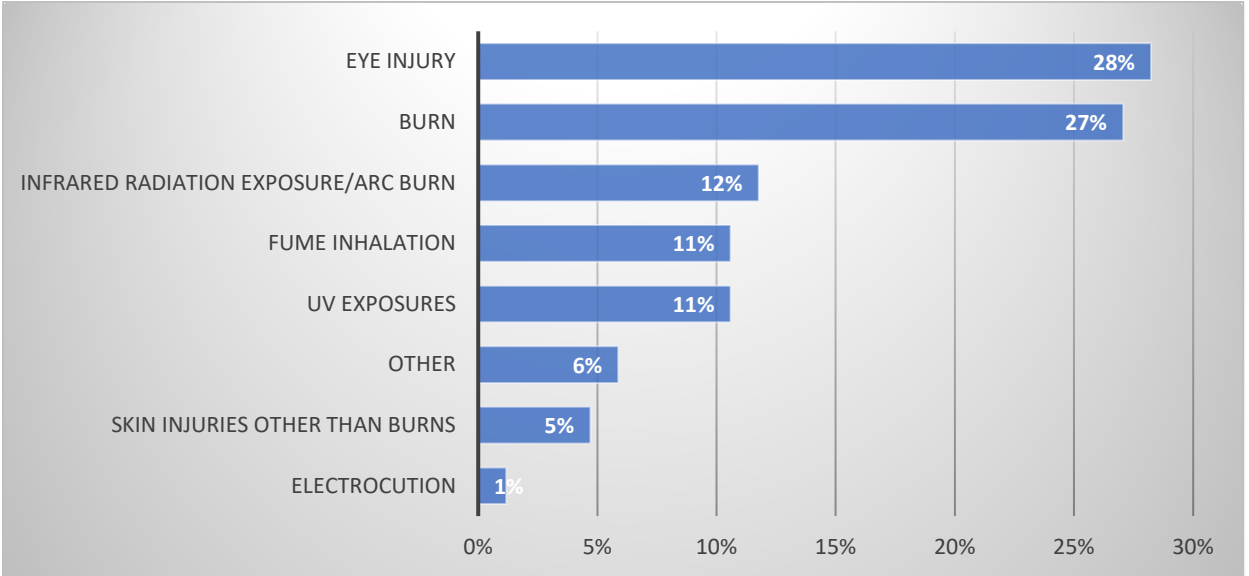


Figure 4: Injuries workers have experienced during welding operations in the past 12 months

Eye injuries can be prevented by using appropriate eye protection and/or welding helmets, and most burns can be prevented from the use of safety gloves, welding aprons, and welding jackets. Comparing the most common welding injuries with the safety measures with the lowest levels of adoption and provision, it appears that increasing those levels could mitigate those most common injuries – though further investigation would be needed to confirm or disprove this. For example, in the “general PPE” category,

the top 3 safety measures not provided by companies were welding aprons, welding helmets, and welding jacket.

Based on the survey, the simpler or quicker the task, the more likely welders are to be injured due to both job reasons and personal reasons; the two most common responses were personal preference (64%) and physical discomfort (63%).

Understanding common injuries and currently used preventative measures (besides training) contributes to a more complete understanding of the current state and outcomes of the baseline adoption levels. Table 3 captures the managerial efforts used most often to encourage adoption of safe practices, besides formal training.

Table 3: Other Measures Besides Formal Training and Safety Meetings

#	Answer	%
1	Toolbox talks on welding hazards	27%
2	A consistent emphasis on safety culture and attitude of safety/acceptance	24%
3	More flexible gear/equipment to meet different body types/sizes	15%
4	More regular maintenance, inspection, and cleaning of safety and welding equipment	14%
5	Poster/handouts related to welding	10%
6	Mentorship program for welders	9%
7	Other	Less than 1%

Interviews with Welders

The last question on the national survey was a request to interview respondents for more detailed feedback, which resulted in interviews with four welders. All four had 15+ years of industry experience and had worked at multiple companies. Their responses aligned with the national survey. One key piece of feedback was that they had heard that non-union welders/companies had different experiences, particularly that non-union companies provided less or no safety gear is and the overall safety environment was quite different.

Due to the comments in the interviews and high participation by union-shop employers and their managerial safety personnel who are part of SMACNA and the MCAA, the researchers sought responses from welders employed by small non-union employers to strengthen the study. The welders were identified with the assistance of a welding supply vendor located in Arizona (a right-to-work state), and the researchers interviewed the welders as they visited the vendor’s locations. Twenty-three welders participated, responding about areas such as: company size/info, company-provided welding safety equipment, satisfaction with company-provided welding safety equipment, overall safety, and adoption level (interview questions are provided in Appendix D).

Company Info

All of the welders said the company they work for had fewer than 10 employees, with 68% having 5 or fewer. The primary industries of the companies were: light gauge steel, industrial, structural steel, and/or operations and maintenance. More details are provided in Appendix E.

Safety Measures and Equipment Provided

Over 90% of the welders regularly welded as their main job duty. When asked about the welding safety measures and equipment their company provided, 57% stated that their company provided general PPE only (such as gloves, eye, and ear protection), while 43% stated their company did not provide any safety measures or equipment (welding-specific or general PPE). With the hazards involved in welding, it is surprising to see such a high rate of companies not providing PPE. When presented with the Comprehensive Welding Safety Measures List, the majority of the interviewees stated that their companies did not provide

“General PPE” and generally commented that they were not familiar with the rest of the areas and/or got frustrated that their company didn’t provide even the most “basic” measures. Table 4 compares the national survey results and small company welder interviews. While the general PPE safety measures are ranked similarly, the percentages of companies that do not provide is much higher in the southwestern small business interviews.

Table 4: What kind of welding safety measures does your company **not provide?**

#	Answer	SW Small Businesses (N = 23)	National Survey (N = 124)
1	Welding aprons	100%	20%
2	Welding helmets	100%	10%
3	Welding jacket	100%	6%
4	Welding gloves	100%	2%
5	Eye protection	70%	2%
6	Other: General hand protection	76%	n/a
7	Other: General ear protection	74%	n/a

Satisfaction

Understanding that the welders in the Southwest might have different experiences those in the national survey, the researchers measured the average satisfaction with safety measures and equipment their company provides. The average satisfaction was a “5” out of a scale of “1-10”, with “1” meaning extremely dissatisfied and “10” meaning extremely satisfied (Figure 5). When asked why their company doesn’t provide the desired measures and equipment, the most common response (45%) was money. Other factors included new business/lack of leadership/small company (20%), too many different types of work (20%), or safety not being valued (15%).

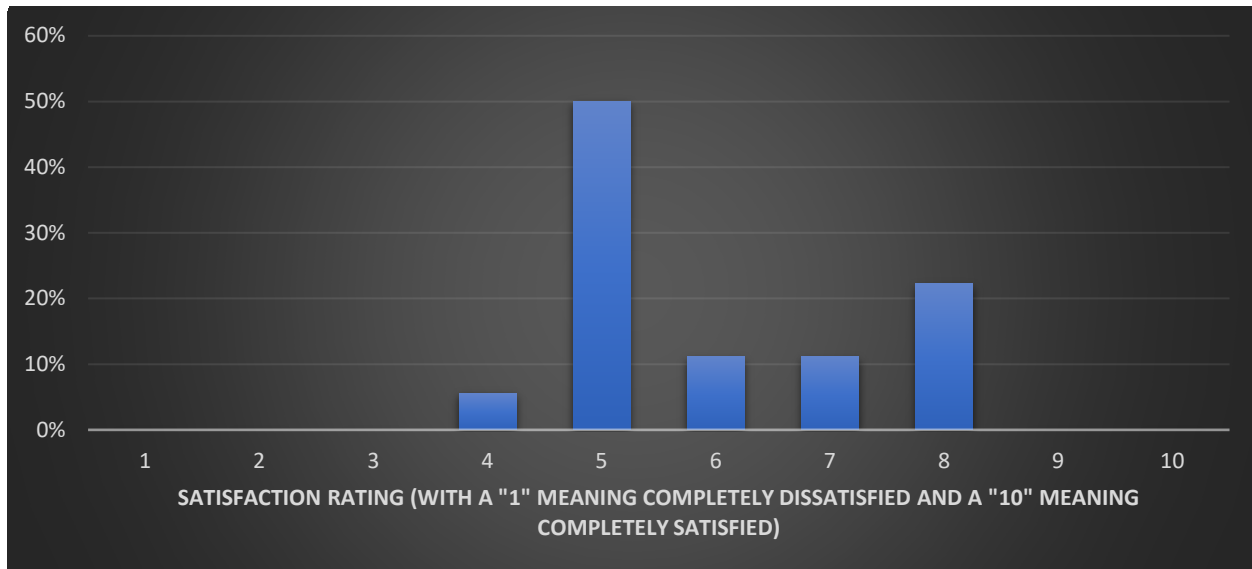


Figure 5: Welders' Satisfaction with the Safety Equipment provided by their company.

Welding Safety

The overall safety of the welding industry was also discussed, as well as adoption of welding safety measures and equipment. Welders rated the overall safety of welders in industry a “5” on average, out of a scale of “1-10”, with “1” meaning extremely unsafe and “10” meaning extremely safe.

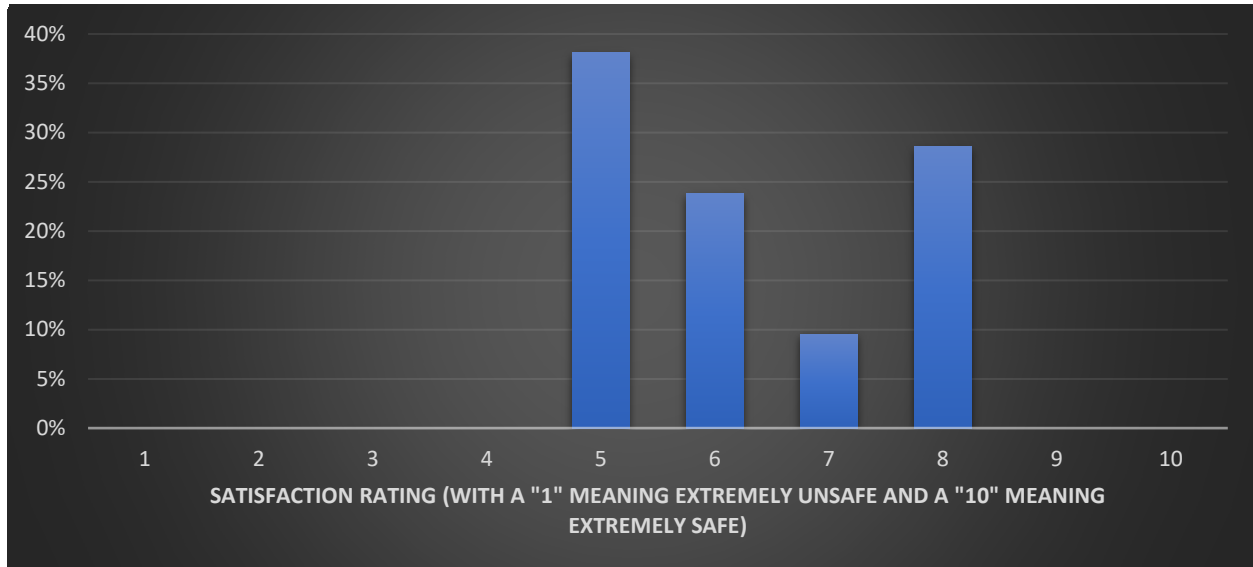


Figure 6: Welders' Perception of the Safety of Welders in Industry

Reasons and Behaviors

When PPE was provided, welders stated that the most common reason their co-workers chose to not wear PPE was because a job was simple/quick. Other common reasons related to perceived hassle, such as when safety equipment may be inside a truck parked far away, and one female welder said that the equipment provided did not fit her properly. A comparison of the national survey results and small company welder interviews is presented in Table 5. The top-ranked reasons are mostly similar, with the welder interviewees not stating “personal preference” for a specific brand, type, etc. as being a reason (likely due to 43% of companies not providing any safety measures) and the national survey not stating “don’t want to purchase” (as majority of companies do purchase).

These findings indicate that strategies to encourage adoption should be clear that these are not valid reasons for not using safety measures when welding. Future research should seek to discover how these reasons can be addressed to positively impact adoption.

Table 5: Top Reasons for Why Welders Don’t Like to Use the Safety Measures

SW Small Business	National Survey
Inconvenient, too much trouble, stuck in old ways (36%)	Personal preference (64%)
The job is simple/quick (29%)	The job is simple/quick (64%)
Makes me feel uncomfortable (14%)	Makes me feel uncomfortable (63%)
Left in my truck and it's too far away (14%)	Inconvenient, too much trouble, stuck in old ways (60%)
Lack of knowledge/training (4%)	Other: Various (53%)
Other: Don’t want to purchase (4%)	It is not possible to bring equipment into the space where I’m working (36%)

Grinder machine safety, while not specifically a welding activity itself, emerged as a common concern in the interviews. With most stating that safety protocols with this equipment in related welding operations are commonly not adhered to (guards removed, wrong size blade for that grinder, etc.). Many of the welders interviewed had severed finger(s) due to grinder and cutting injuries. Welders often mentioned seeing many more potential incidents related to removal of the guards on grinders and “close calls” that did not result in injury but were unsafe. Machine guarding is regularly a top ten most common OSHA citation. Further, companies that recently had a welding injury stated that there was greater awareness of safety measures and equipment among other welders immediately after that injury/incident.

Conclusion

Sheet metal and HVAC workers are exposed to harmful welding fumes and nanomaterials. By measuring the provision and adoption levels of safety interventions, this project quantifies necessary industry benchmarks. Interviews and targeted surveys with members of two leading contractor associations were conducted. This research led to the development of a comprehensive list of welding safety measures and interventions list that can mitigate fumes and nanomaterials. Information from welders employed by small businesses with less than 10 employees was also collected.

Based on the national survey, companies were least like to provide 3rd party occupational studies of employees’ health, wet slurry vacuum to remove coatings, welding aprons, conduct 3rd party welding fume studies, laser welders, fume extractor guns, vacuum systems, and ergonomic considerations. Eye injuries and burns were the most common welding injuries within the past 12 months. Job/task simplicity and personal preference (or physical discomfort) are the most common reasons respondents heard for why welders do not use welding safety measures. Follow-up interviews with welders employed by companies that responded to the national survey identified differences at union companies vs. companies in right-to-work states.

Interviews with welders employed by small businesses in the Southwest showed fewer employers provide welding safety measures or even general PPE, which is alarming. Grinder machine safety is a common concern, as safety protocols with this equipment in related welding operations are commonly not adhered to (guards removed, wrong size blade for that grinder, etc.). Companies that recently had a welding-related injury stated that there was greater awareness of safety measures among other welders immediately after that injury/incident.

When comparing the top reasons welders from the national survey and Southwest gave for not using safety measures, there were several common responses: convenience/trouble and old habits, job simplicity, and personal comfort. Future research should focus on how to address these most common reasons, as they are a hindrance to adoption. Based on interview comments from some welders, their injuries were also a result of perceived job simplicity and old habits. Research that ties welding injuries back to job characteristics and worker demographics would be useful in exploring this topic. To address personal comfort reasons, research could be conducted more closely with safety device/equipment manufacturers and ergonomic considerations to explore this concern. Future welding research should continue to explore differences among union and non-union employers. Future research on the frequency of specific types of welding injuries and the adoption level of the corresponding safety measures would be useful.

Future Funding Plans

The following list of topics are being proposed to MCAA, SMACNA, and southwestern contractors for further consideration and exploration:

- Focused study on reasons companies do not provide safety interventions and what to incentivize them to do so.
- Focused study on the relationship between the frequency of specific types of welding injuries and the provision and adoption (use of the corresponding safety measures).
- Comparison of union vs non-union shops related to safety equipment, training, and injuries
- Comparison of small business vs large business related to safety equipment, training, and injuries
- Testing of policies, practices, and training adjustments to increase levels of adoption of safety measures
- Exploration of effective training adjustments for use of proper safety measures on “quick and simple” tasks
- Workforce safety sampling of welder tasks in Large, Medium, and Small Firm Weld Shops
- Study of near-miss incident rate for various welder related injuries.

Based on the findings of this research, future research that explores the differences between union vs. non-union employers regarding welding safety measures should be explored. Further, as this research provides a framework for important safety benchmarks and adoption metrics, the researchers are exploring using similar research methods beyond welding operations, such as other common operations/tasks (working in confined spaces, electrical work, roofing, etc.). The researchers continue to seek out research sponsors that are interested in measuring construction workers’ reactions to changes, such as implementing safety measures, new procedures, protocols, and other related tools/systems.

List Of Presentations/Publications

- SMACNA Safety Committee Annual Meeting, May 4th, 2022
- The researchers have submitted sections of this study to the Architectural Engineering Institute (AEI) of ASCE’s 10th Biennial Professional Conference for April 2023

Dissemination Plan

The researchers have submitted sections of this study in academic journals and conference proceedings. The researchers also plan to submit a comprehensive journal paper from the study to a top academic journal. They will also share this report with

- Survey respondents
- Southwestern companies that participated in the interviews
- SMACNA leadership for access by their members
- MCAA leadership for access by their members

Appendix A – Welding Safety Gear List

WELDING SAFETY GEAR LIST

<p>1 – General PPE</p> <ol style="list-style-type: none"> 1. Eye protection 2. Welding gloves 3. Welding helmets 4. Welding aprons 5. Welding jacket 	<p>2 – Ventilation equipment</p> <ol style="list-style-type: none"> 1. Shop ventilation 2. Point of operation ventilation / welding fume extractors (smoke eaters) 3. Fume hoods 4. Fume extractor guns 5. Vacuum systems 6. Powered air purifying respirator (PAPR)
<p>3 – Policies/procedures</p> <ol style="list-style-type: none"> 1. Written/published document/checklist of safety practices/steps to take when welding 2. Job hazard analysis (JHA) 3. Hot work permits 4. Hexavalent Chromium protocols 5. Ergonomic considerations for welding 	<p>4 – Materials & equipment</p> <ol style="list-style-type: none"> 1. Flash shields 2. Offer a variety of welder machines (flux, shielded metal, gas metal, etc.) 3. Wet slurry vacuum to remove coatings 4. Tools and procedures to encourage the removal of coatings before welding, as needed. 5. Laser welders
<p>Other</p> <ol style="list-style-type: none"> 1. Conduct 3rd- party welding fume studies 2. 3rd-party occupational studies of employees' health (i.e. standard health screening) 	

Appendix B – National Survey

Protecting Workers from Welding Fumes (CPWR small study no. 21-8-PS)



The purpose of this survey is to **better understand the implementation and usage of safety measures** to reduce workers' exposure to harms arising from welding. Safety measures include devices and personal protective equipment (PPE), such as shields, ventilation equipment, and other tools/processes. We are looking to identify potential resistance and barriers to utilizing safety measures so the industry can more **effectively work towards reducing or eliminating these hazards**. We are ASU researchers conducting this study with the support of the Center for Construction Research and Training (CPWR).

- [Download a free welding safety resource guide](#)
- The survey should take **5-7 minutes** to complete & consists of **18 questions**.
- Once completed, you will have the option request a **free copy of this study** (to be published in Fall 2022)

You may start the survey and save for later completion. The results will only be shared in the aggregate form and may be used in reports, presentations, or publications, but **your name will not be used**. The research team will only collect name and email, if you are interested, to participate in an interview. **You may opt out at any time**. There are no foreseeable risks or discomforts to your participation. If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788

Please contact Kenneth Sullivan at kenneth.sullivan@asu.edu if you have any questions about the survey and this research.

You must be 18 or older to participate in the study. **With full knowledge of all foregoing, I agree, on my own free will, to participate in this survey.**

SECTION #1: WELDING AT YOUR COMPANY

Please answer the following questions about the welding that's done at your company.

1. How many workers in your company are **trained and authorized** to conduct welding (can be different types of welding)?
 - a. 1-5 workers
 - b. 6-10 workers
 - c. 11-20 workers
 - d. More than 20 workers

2. **Where** do your workers spend most of their time welding? (Select all that apply)
 - a. Construction/on-site
 - b. Fabrication shop
 - c. Other: _____
3. Of workers that are **authorized** to weld, what **% of their typical workday is spent welding?**
 - a. Less than 10% of their day
 - b. 11%-25% of their day
 - c. 26%-50% of their day
 - d. 51%-75% of their day
 - e. Greater than 75% of their day
4. **How are your workers trained** to weld and about welding safety?
 - a. Formal Apprenticeship program (JATC or other)
 - b. Union specialized classes
 - c. Formal education program at a community college
 - d. Certificates/other training programs
 - e. As part of their new hire training programs
 - f. Regular internal training at our company
 - g. Virtual reality welding training
 - h. Other: _____

SECTION #2: USE OF SAFETY MEASURES

Please answer the following questions about **“safety measures” = any devices and personal protective equipment (PPE), such as shields, ventilation equipment, etc.** ([click here for a full list](#)) that are used to reduce risk that workers have of exposure to welding fumes and other particles/hazards.

5. Please identify **how often you hear** welders say the following job/task reasons about why they may not always choose the safety measures.
 - a. I hear this regularly.
 - b. I hear this somewhat often.
 - c. I’ve heard this before on occasion.
 - d. Not common
 - e. I’ve never heard this before

	1	2	3	4	5
The job is simple/quick (I’m just tack welding)					
I left my gear back at the tool crib and just wanted to weld a few to get going.					
It’s not possible to bring equipment into the space that I’m working.					
I’m going to multiple sites and don’t have time to re-setup safety gear.					
Safety makes them feel rushed to finish the job, safety would take away time from the job, etc.					
Other: _____					

6. Please identify **how often you hear** welders say the following personal reasons about why they may not always choose to use safety measures.
- I hear this regularly.
 - I hear this somewhat often.
 - I've heard this before on occasion.
 - Not common
 - I've never heard this before

	1	2	3	4	5
Personal preference (I want to use my own gear, this isn't the brand I like, etc.)					
Physical discomfort (I'm not comfortable using this gear)					
Physical inability to use (for example, they have a physical impediment that prevents them from being able to wear a mask, decreased lung capacity due to smoking, asthma, previous injury, etc.)					
"Machoism", a commonly used phrase for this reason: "real men don't do/use this."					
Been in the industry too long, stuck in their own ways of doing things.					
Unsure of how to use it properly and/or have not received adequate training.					
Other: _____					

7. Rate your agreement with the following statement: "When welding, getting our workers to **always take the most appropriate safety** precautions is easy."
- Completely Agree
 - Mostly Agree
 - Slightly Agree
 - Neither Agree nor Disagree
 - Slightly Disagree
 - Mostly Disagree
 - Completely Disagree
8. Which of the following safety measures does your company **not provide or not require** (understanding that some may be used, depending on the job)?
- General PPE (select what your company does **not provide**)
 - Eye protection
 - Welding gloves
 - Welding helmets
 - Welding aprons
 - Welding jacket
 - Ventilation equipment (select what your company does **not provide**)
 - Shop ventilation
 - Point of operation ventilation/welding fume extractors (smoke eaters)
 - Fume hoods

- iv. Fume extractor guns
 - v. Vacuum systems
 - c. Policies/procedures (select what your company does **not provide**)
 - i. Written/published document/checklist of safety practices/steps to take when welding
 - ii. Job hazard analysis
 - iii. Hot work permits
 - iv. Hexavalent chromium protocols
 - v. OSHA standards
 - vi. ANSI/AWS standards
 - vii. NIOSH guidelines
 - viii. Ergonomic considerations for welding
 - d. Materials & equipment (select what your company does **not provide**)
 - i. Flash shields
 - ii. Offer a variety of welder machines (flux shielded metal, gas metal, etc.)
 - iii. Wet slurry vacuum to remove coatings
 - iv. Tools and procedures to encourage the removal of coatings before welding, as needed
 - v. Laser welders
 - e. Other (select what your company does **not provide**)
 - i. Conduct 3rd party welding fume studies
 - ii. 3rd-party occupational studies of employees' health (i.e. standard health screening)
 - iii. Other: _____
9. Specific to limiting the risk of exposure to welding fumes and other particles, what other safety measures, tools, systems, practices, etc. do you implement? (This can include checklists, safety guides, procedures, etc.). The purpose of this question is to expand on the list we provided to you to raise awareness and promote safe practices across the industry.

10. Sometimes a worker may be welding near a fume extractor, but doesn't place the extractor in the proper position, has a helmet, but forgot to put it in the down position, etc.

If you were to walk your shop/construction site right now, pick the top three (3) safety measures that workers **are not using (and should be using) or not using properly**.

- a. Welding gloves
 - b. Welding helmets
 - c. Welding aprons
 - d. Welding jacket
 - e. Fume hoods
 - f. Point of operation ventilation/welding fume extractors (smoke eaters)
 - g. Hot work permits
 - h. Hexavalent chromium protocols
 - i. Wet slurry vacuum to remove coatings
 - j. Other: _____
11. What injuries have your workers experienced during welding operations in the past 12 months? (Remember, this survey is anonymous) (select all that apply)

- a. Eye injury
 - b. Burn
 - c. Skin injuries other than burns
 - d. Infrared radiation exposure/arc burn
 - e. UV exposures
 - f. Electrocution
 - g. Fume inhalation
 - h. Other: _____
12. What other measures besides formal training and safety **meetings does your company use to encourage workers to be safe when welding?** (select all that apply)
- a. Poster/handouts related to welding
 - b. Toolbox talks on welding hazards
 - c. More flexible gear/equipment to meet different body types/sizes
 - d. A consistent emphasis on safety culture and attitude of safety/acceptance
 - e. More regular maintenance, inspection, and cleaning of safety and welding equipment
 - f. Mentorship program for welders
 - g. Other: _____
13. Rate your agreement with this statement: *“My company’s management values welding safety equal or greater than welding production.”*
- a. Completely Agree
 - b. Mostly Agree
 - c. Slightly Agree
 - d. Neither Agree nor Disagree
 - e. Slightly Disagree
 - f. Mostly Disagree
 - g. Completely Disagree
14. How would you describe your company’s safety structure? (Select all that apply)
- a. We have a safety department/group that consists of multiple staff whose job it is to manage out safety program across projects/jobs.
 - b. We have 1-2 staff whose job it is to manage our safety program across projects/jobs in addition to other job responsibilities.
 - c. We have 1 person that dedicates part of their time to manage our safety program across projects/jobs in addition to other job responsibilities.
 - d. None of the above
 - e. Other: _____

SECTION #3: BACKGROUND QUESTIONS

Please answer the following questions to provide some additional information about your company.

15. Please estimate your company’s **total number of manhours** per year.
- a. Under 25,000 manhours
 - b. 25,001-50,000 manhours
 - c. 50,001-100,000 manhours
 - d. 100,001-200,000 manhours
 - e. 200,001-300,000 manhours
 - f. 300,001-400,000 manhours
 - g. 400,001-500,000 manhours
 - h. Over 500,000 manhours

16. Approximately how many **full-time employees** (including field and office staff) are within your company?
- a. Less than 10
 - b. 10-19
 - c. 20-49
 - d. 50-99
 - e. 100-499
 - f. 500+
17. What are your company's **most common jobs/types** of work performed? (pick 3)
- a. Commercial HVAC
 - b. Industrial
 - c. Facility operation & maintenance
 - d. Refrigeration
 - e. Controls
 - f. Certified pressure vessel welds
 - g. X-ray welds
 - h. Other: _____
18. How many years of **industry experience** do you have?
- a. Less than 5 years
 - b. 5-9 years
 - c. 10-19 years
 - d. 20-29 years
 - e. 30-39 years
 - f. 40+ years
19. Which of the following best describes your current **job position**?
- a. Safety professional/manager/director
 - b. Non-supervisory (front line/project team member)
 - c. First tier supervisor (project manager, foreman, crew lead)
 - d. Second tier supervisor (regional manager, general foreman, director, etc.)
 - e. Senior Executive (AVP, VP, C-suite)
 - f. Other: _____

Would you be willing to participate in a short phone call (15 minutes) to share more about your experiences?

Please leave your name and email (this will not be connected with your survey response):

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Appendix C – National Survey Respondents’ Demographics

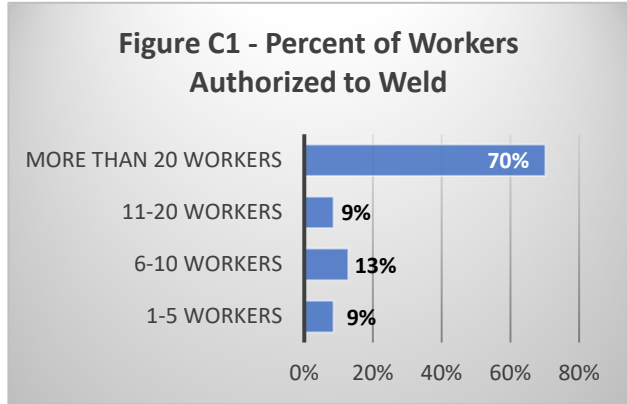


Table C1 - Company's Total # of Manhours (MH) per Year

#	# of MH Per Year	%
1	under 25,000 manhours	4%
2	25,001-50,000 manhours	1%
3	50,001-100,000 manhours	11%
4	100,001-200,000 manhours	17%
5	200,001-300,000 manhours	8%
6	300,001-400,000 manhours	12%
7	400,001-500,000 manhours	5%
8	Over 500,000 manhours	41%

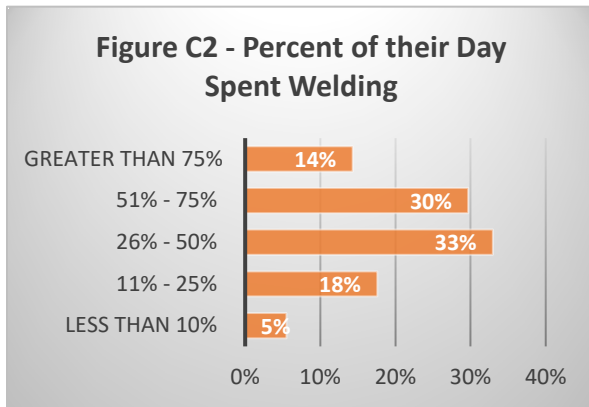
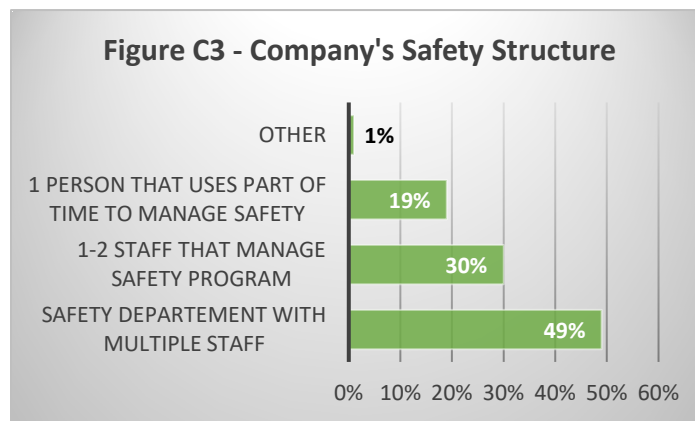


Table C2 - Most common jobs/types of work performed

#	Job Types	%
1	Commercial HVAC	28%
2	Industrial	25%
3	Facility Operation & Maintenance	18%
4	Refrigeration	10%
5	X-ray Welds	7%
6	Controls	6%
7	Certified pressure vessel welds	3%
8	Other	3%



**Figure C4 - How Workers Are Trained About Welding Safety
(select all that apply)**

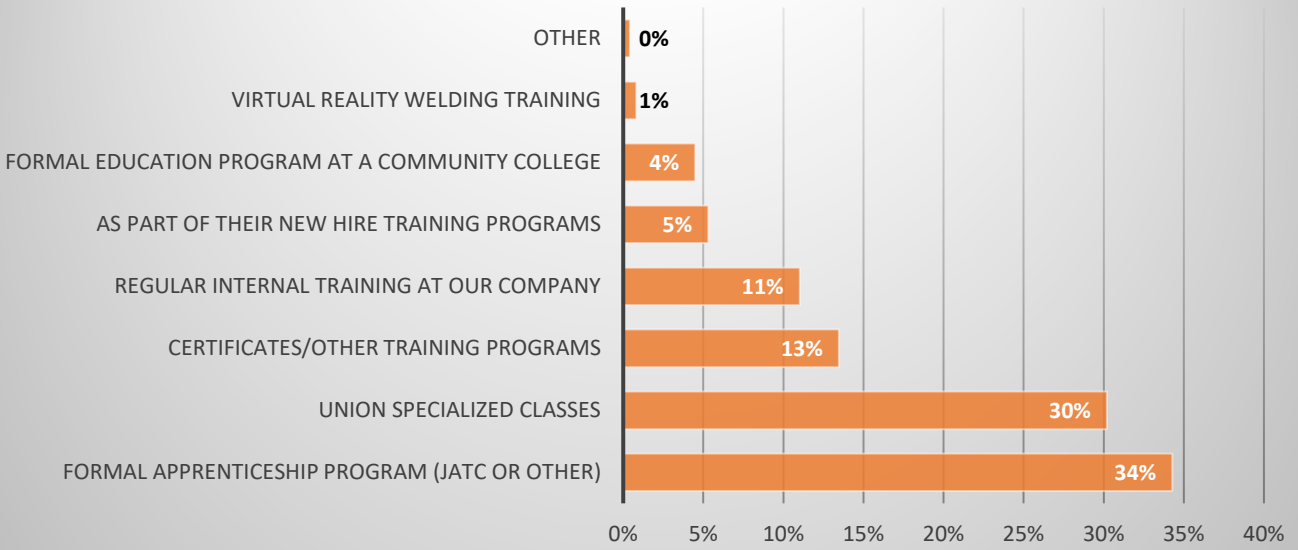


Table C3 - Respondent's current job position

No.	Job Position	%
1	Safety professional/manager/director	38%
2	Non-supervisory (front line/project team member)	1%
3	First-Tier supervisor (project manager, foreman, crew lead)	14%
4	Second-Tier supervisor (regional manager, general foreman, director, etc.)	14%
5	Senior Executive (AVP, VP, C-suite)	26%
6	Other	5%

Appendix D – Southwest Welder Interview Questions:

1. What kinds of jobs does your company do?
 - (1) Structural Steel
 - (2) Light gauge steel
 - (3) Industrial
 - (4) Operations & Maintenance
 - (5) Refrigeration/Controls
 - (6) Other: _____
2. Do you weld?
 - (1) Yes
 - (2) No
3. What is your role?
 - (1) Field front line
 - (2) Supervisor – foreman, crew lead
 - (3) General Management- general foreman
 - (4) Other: _____
4. How many welders do you have at your company? : _____
5. On a scale of 1-10 (10= extremely satisfied and 1=extremely unsatisfied), how would you rate your overall satisfaction with the welding safety equipment provided by your company?
: _____
6. Does your company:
 - (1) Provide welders with safety gear?
 - (2) Or do they need to use their own?
7. What kinds of gear does the company provide? (review printed list)
 - (1) Why do you think the company doesn't provide much gear?
8. On a scale of 1-10 (10= extremely safe and 1=extremely unsafe), how would you rate the overall safety of welders in the welding industry? : _____
9. If less than an "8", what do you think would convince more welders to use safety gear?
: _____
10. Is there any gear they don't like to use? (Review printed list)
11. Why? (Review printed list of top reasons)

Appendix E – Southwest Welder Interviews’ Demographics:

Table E1 - Most common jobs/types of work performed

#	Job Types	%
1	Structural steel	22%
2	Light gauge steel	22%
3	Repairs	19%
4	Industrial	15%
5	Facility Operation & Maintenance	7%
6	Commercial HVAC	4%
7	Refrigeration/controls	4%
8	Solar panels	4%
9	Other/Misc.	3%

Table E2 - Respondent's current job position

#	Job Types	%
1	Field Front Line	55%
2	Supervisor-foreman, crew lead	18%
3	General management	9%
4	Owner	14%
5	Maintenance officer	5%

