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Safety Hazard Analysis of an Arc Welding Machine

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Abstract: A system safety analysis of a Lincoln Electric AC/DC 225/125™ Stick Welder machine was completed. First, injury and illness data from the OSHA Accident database, other OSHA publications, as well as other materials from the American Welding Society were reviewed. A copy of the owner's manual was also obtained and reviewed. The various sources were then used to prepare a Preliminary Hazard Analysis which showed eight distinct hazards: primary voltage shock (DC), secondary voltage shock (AC), exposure to fumes and gases, thermal burns, fire and explosions, UV exposure, musculoskeletal Injuries, and noise. Using the same data sources, the effects of each of the hazards were identified, as well as the controls needed for each hazard. This information was then used to prepare a Fault Tree Analysis showing the combinations of conditions which permitted the various types of injury-causing accidents to occur. The Fault Tree Analysis also clarified the necessity of using safe work practices and adequately maintained equipment. A Failure Modes & Effects Analysis was then conducted to demonstrate the various ways in which components of the welding machine or the personal protective equipment (PPE) might fail and result in injury or in equipment damage. These various failure modes were each examined, and their effects noted on the operation of the welding machine, as well as the safety of the operator. The effects of PPE failures, including unused or improperly used PPE on operator safety were also noted. One interesting observation noted was that in addition to standard "Hot Work" precautions and standard PPE for arc welding, specific types of (consumable) welding rods may require the use of substantially different types of additional PPE in order to weld safely.

***Keywords*:** Preliminary Hazard Analysis, Fault Tree Analysis, Failure Mode Effect Analysis, OSHA, PPE, Welder Machine

1. Introduction

Welding is the joining of the metal parts together by heating the surfaces to their melting point and there are different types of welding. Tack welding, gas metal arc welding (GMAC), flux core arc welding (FCAW), shielded metal arc welding (SMAW), and submerged flame/plasma gouging are some of the examples of welding. We chose an arc welding machine to analyze for safety hazards since a small incident of **Voltage Shock** occurred while the primary author was working as a summer intern with a manufacturing company in Colorado. The operator injured himself by falling off from a ladder during arc welding a can. We worked in the welding/cutting department for conducting time-study and aware that the establishment used a Lincoln Electric arc welding machine for their processes. But, lacked information regarding the specific model number of the arc welding machine. An AC/DC 225/125™ Stick Welder - Lincoln Electric Arc Welding Machine was selected for this safety analysis.

2.0 Accident History Discussion

It was quite difficult to gather the information regarding Arc welding accidents just from the OSHA Accident database as no accident summaries specifically referenced the AC/DC 225/125™ Stick Welder machine welding or accidents that happened with it. However, a fact sheet (https://www.osha.gov/Publications/OSHAfactsheet-eyeprotection-during-welding.html) was found which showed welding operations, applicable OSHA standards, and suggestions for protecting welders & coworkers from exposures. The OSHA standard includes the rules, proposed rules, notices, OSHA compliance directives and letters of interpretation for general, construction, shipyard, and marine industry.

Furthermore, we went through the OSHA Accident Investigation database and found a large list of accidents that happened during the arc welding process in different companies. Figure1 represents some examples of the Arc Welding accidents.

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Accident: 109341.015 - Employee Is Electrocuted While Welding

Accident: 109341.015 -- Report ID: 0524530 -- Event Date: 09/20/2018

Inspection	Open Date	SIC	Establishment Name
1347901.015	09/20/2018		Rockbranch Ironworks, Inc.

At 2:15 p.m. on September 20, 2018, an employee was welding an anchor bracket using a gas powered Shielded Metal Arc Welding (stick) Lincoln Ranger 250GXT welder with direct current electrode positive. A coworker who had been working with the employee did not hear the welder rev up and went to check on the employee. The employee was found standing on the scissors lift with his neck lying on the metal bridge. The local police department arrived and started lifesaving measures; however, the employee was killed through electrocution.

Keywords: welding cable, welding electrode, electrocuted

End Use	Proj Type	Proj Cost	Stories	NonBldgHt	Fatality
Other building	New project or new addition		1		X

Employee #	Inspection	Age	Sex	Degree	Nature	Occupation	Construction
1	1347901.015	32	M	Fatality	Electric Shock	Welders and cutters	**FallDist**: **FallHt**: **Cause**: **FatCause**: Electric shock, other and unknown cause

Accident: 103739.015 - Employee Suffers Second And Third Degree Burns When Welding

Accident: 103739.015 -- Report ID: 0950621 -- Event Date: 02/20/2018

Inspection	Open Date	SIC	Establishment Name
1300729.015	03/09/2018		Hemington Landscape Services Inc.

At 3:30 p.m. on February 20, 2018, an employee was welding a leaking seam on a 50 gallon diesel tank using mig arc welding equipment. The employee was caught in a flash burn when diesel vapors leaked from the tank and ignited. The employee received third degree burns to his upper left arm pit and second degree burns to his upper left arm and hand. The employee was hospitalized.

Keywords: vapor, caught by, hand, diesel fuel tank, burn, arc welding, arm

Employee #	Inspection	Age	Sex	Degree	Nature	Occupation
1	1300729.015	24	M	Hospitalized injury	Burn/Scald(Heat)	Laborers, except construction

Accident: 200602498 - Employee Found Dead After Arc Welding Support Pole

Accident: 200602498 -- Report ID: 0625400 -- Event Date: 08/14/2003

Inspection	Open Date	SIC	Establishment Name
306064924	08/15/2003	1521	Nored Shearer Construction Co.

On August 14, 2003, Employee #1 was assigned to arc weld a support pole in the back yard of a property. He was left alone to perform the job and was later found dead by a coworker.

Keywords: welder, construction, welding, arc welding

End Use	Proj Type	Proj Cost	Stories	NonBldgHt	Fatality
Single family or duplex dwelling	Alteration or rehabilitation	Under $50,000	1		X

Employee #	Inspection	Age	Sex	Degree	Nature	Occupation	Construction
1	306064924			Fatality	Other	Occupation not reported	**FallDist**: **FallHt**: **Cause**: Erecting structural steel **FatCause**: Other

Accident: 202487260 - Employee Is Severely Burned While Arc Welding A Tank

Accident: 202487260 -- Report ID: 0950621 -- Event Date: 05/08/2008

Inspection	Open Date	SIC	Establishment Name
310413919	05/09/2008	7353	Holt Of California - Pleasant Grove Facility

At approximately 11:40 a.m. on May 8, 2008, Employee #1, a field service technician, began arc welding on a tank containing diesel fuel following accepted procedures. Some fuel splashed onto his coveralls, and the flammable vapors ignited as he struck an arc. No fire extinguisher was nearby. He rolled on the ground but the flames on his shoulder reignited his arms and chest. A coworker helped put the flames out by pushing him up against the service truck under a jug of water and trickling water onto him. Employee #1 was hospitalized and treated for second and third degree burns to his arm, shoulder, neck, and face.

Keywords: burn, fire ext system, shoulder, diesel fuel tank, fire, welder, welding, arm, face, tank

Employee #	Inspection	Age	Sex	Degree	Nature	Occupation
1	310413919			Hospitalized injury	Burn(Chemical)	Welders and cutters

Figure 1: Examples of Arc Welding Accidents in OSHA Website

3. Hazard Analysis of the Arc Welding Machine

Arc welding could be quite hazardous if it is not done in accordance with the instructions properly. Burning, electrocuted, fire explosion, and electric shocks are the possible injuries that could occur. The manual for AC/DC 225/125 welding machine contains a detail discussion of safety precautions, installation and operation instructions, part list description.

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We have used this data source to do our safety analysis on the arc welding machine and the analyses result is not limited to only the specific kind of arc welding machine mentioned above.

4. Safety Analysis

Below we will describe three techniques to conduct the safety analysis of an arc welding machine.

4.1 Preliminary Hazard Analysis (PHA)

It is the simplest kind of safety analysis technique that can be used to determine the root cause of the problem. Below is shown a PHA for the Arc Welding Machine.

Table1. Preliminary hazard analysis for the Arc Welding Machine.

Hazard	Cause	Effect	Corrective Measure
Primary Voltage Shock (DC)	Occurs when a welder touches electrically "hot" parts inside the welder case or the electric distribution system to which the welder is connected.	1. Severe injury or death 2. Sudden fall caused by the electric shock	1. Always be sure to repair or replace damaged insulation before use 2. Wear dry rubber gloves
Secondary Voltage Shock (AC)	When a worker holds a bare wire in one hand and a second bare wire with another, electric current will pass through that wire and through the welding operator	1. Make the person holding the wire unable to let go and stop heart beating 2. Severe injury or death	1. Wear dry rubber gloves 2. Never touch the electrode or metal parts of the electrode holder with skin or wet clothing 3. A safety type disconnecting switch should be installed near the machine 4. Hot metals should be handled using tongs or pilers 5. An insulating mat must be use if the welding is done on steel or any other conductive material.
Fumes and gases	Over exposure to welding fumes as it contains potentially harmful complex metal oxide compounds from consumables, base metal and the base-metal coatings	1. Short-term exposure can result in nausea, dizziness, or eye, nose and throat irritation. 2. Prolonged exposure can lead to cancer of the lung, larynx and urinary tract, as well as nervous system and kidney damage	1. Use a ventilation system- such as a fan, and an exhaust system or fixed or removable exhaust hoods 2. Welding operators should wear an approved respirator unless exposure assessments are below applicable exposure limits 3. Employer and employee should be of aware of the permissible exposure limits (PEL) for the substances in welding fume and take care not to exceed them
Fire and explosions	1. The welding arc creates extreme temperatures(up to 7000 degrees Fahrenheit for Arc welding) 2. The intense near the arc and the heat, sparks and spatter created by the arc 3. Weld directly on the concrete floor	1. Significant fire and explosions can burn the plant 2. Severe injury or death 3. Heat from the welding could build up beneath the floor and create explosion.	1. Know where the fire alarms and extinguishers are located 2. check the extinguisher's gauge to make sure it is full 3. If an extinguisher is not available, be sure to have access to fire hoses, sand buckets or other equipment that douses fire 4. Know where the exit is 5. Use metal sheets or fire-resistant curtains as fire barriers. 6. Floor should be filled to prevent sparks and hot metal from entering.

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Hazard	Cause	Effect	Corrective Measure
			7. No welding operation should be done on used drum, tank or container that contained any chemical
Musculoskeletal Injuries	Poor work postures, maintaining a static posture for long durations without rest breaks.	1. Back injuries, shoulder pain, tendinitis, reduced muscle strength, carpal tunnel syndrome, white finger, and knee joint diseases	1. Proper lifting 2. Not working in one position for long periods of time 3. Keeping the work at a comfortable height 4. Using a footrest when standing for long periods 5. Locating tools and materials conveniently 6. Minimizing vibration
Noise	Welding activities such as flame cutting and air arc gouging can produce noise levels of over 100 dB(A), whereas a loud noise is above 85 dB(A)	1. Ringing in the ears, known as tinnitus. 2. Occasional dizziness, known as vertigo. 3. Increased heart rate.	1. Correct & consistent use of hearing protection such as ear plugs or muffs.
Ultraviolet radiation	While joining the two metal parts, the arc creates intense and ultraviolet radiation	1. Burn injuries on the face 4. Can harm eyes	2. Operators should wear hood, face shield, or goggles with appropriate filter lenses. The filter plate should be at least shade #10 for general welding up to 200 amps
Severe Burn	While welding if molten metal touches the skin or clothing the operator is wearing	1. Burn injuries from sparks or molten slag entering the shoe	1. Operators should wear long sleeve shirts and welding overalls 2. A pair of high-top leather shoes, preferably safety shoes, is good protection for the feet. 3. Shirts and trousers should be made of cotton or a flame-resistant material; synthetic fibers will burn and melt the human skin. 3. Hot metal should be handled with metal tongs or pliers.

4.2 Fault Tree Analysis

The fault tree analysis for the 225 Amp Arc/Stick Welder AC225S, 230V is shown below in Figure 2.

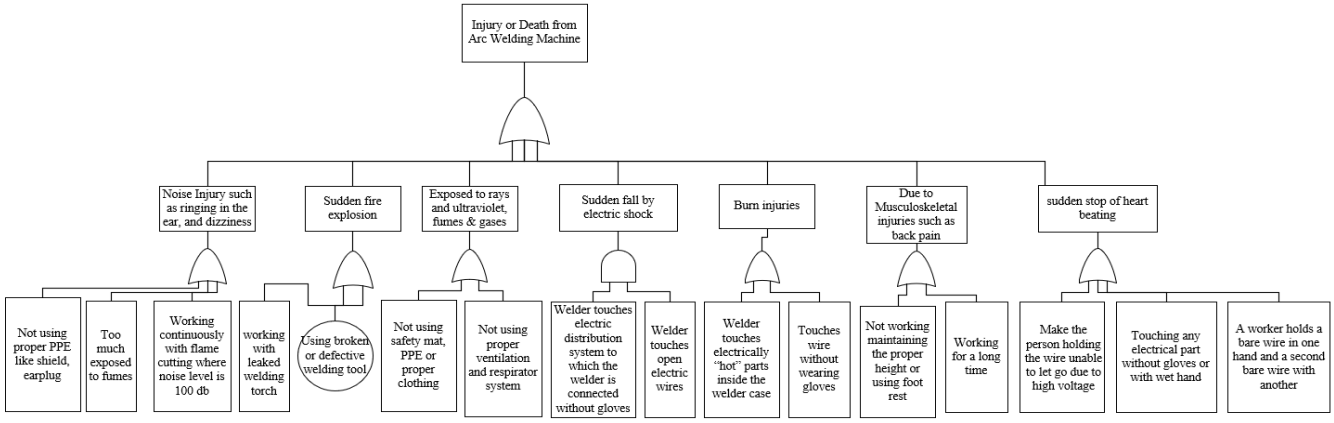

Figure 2 : Fault Tree Analysis for 225 Amp Arc/Stick Welder AC225S, 230V

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4.3 Failure Mode and Effect Analysis (FMEA)

The FMEA for the arc welding machine is shown below in Table 2.

Table 2: FMEA for 225 Amp Arc/Stick Welder AC225S, 230V

Process Function	Potential Failure Mode	Potential Effect(s) of Failure	Severity	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Process Controls	Detection	RPN	Recommended Action(s)	Action Results			
											Sev	Occ	Det	RPN
Arc Welding Machine	1.Electric Shock	Death, severe injury, sudden fall cause by the electric shock, stop beating the heart and make the person holding the wire unable to let go	9		Not using rubber gloves and safety mats, touching hot metal with hand	4	Operators wear gloves and proper insulating dress	3	108	Use of safety mats, hot metals should be handled by tong, a safety type disconnecting switch should be installed near the machine	9	4	3	108
	2.Burn Injury	Death, severe injury	7		When molten metal touches the skin or clothing, severe electric shock	4	Operators wear gloves, still toe shoes and proper insulating dress	3	84	Shouldn't touch the parts with wet hand, use personal protection equipment like hooded shield for face				
	3.Fire and Explosions	Severe injury, heat from the welding could build up beneath the floor and create explosion	9		Weld directly on the concrete and on used chemical container, gas leakage from the torch nozzle,	2	Fire alarms starts to beep, fire extinguisher is close by the welding operation so that the other operators can diffuse the fire, first aid and fire-blanket available	5	90	Welding should be done on a safe fire-brick safe system				
	4.Musculoskeletal Injuries	Carpal tunnel, knee joint diseases, white finger, back injuries, shoulder pain and reduced muscle strength	3		Welding on a uncomfortable height, not using proper lifting system and weld for a long time	3	Operators have a rule to take break after a certain period of welding	4	36	Using footrest				
	5.Noise Injuries	Ringing in the ear know as tinnitus	3		Continuous flame cutting and air arc gouging can produce noise levels of over 100 dB(A), whereas a loud noise is above 85 dB(A)	3	Operators use hear aid	3	27	Annual ear check should be done by the management. If the operators are working in continuous high frequency sound, then they should take break more frequently.				

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	6.Rays and Ultraviolet Injuries	Burn injuries on the face, eye injury	7		While joining the two metal parts not using proper eye and face shield, also PPE	3	Operators use proper curtain and shield.	4	84	Operators should wear googles with #10 filter shield				
	7.Gas and Fume Injures	Short-term exposure can result in nausea, dizziness, or eye, nose and throat irritation and prolonged exposure can lead to cancer of the lung, larynx and urinary tract, as well as nervous system and kidney damage	3		Working without PPE, exposed continuously to the fumes	2	The operators take break while working and wear proper respirator system.	4	24	Use of ventilation system such as a fan or exhaust system				

5. Conclusion

rforming these safety analyses was a valuable learning experience for us. While we were unable to identify the del of the arc welding machine, this analysis addresses several hazards common to most if not all arc welding machines. It relied on both product information specific to this machine, as well as other sources such as the those available from OSHA.

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