Reducing the Noise Generated During Air-Arc Gouging Can be as Simple as Flipping a Switch

U.S. Department of Labor
Hilda L. Solis, Secretary

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Joseph A. Main, Assistant Secretary

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Reducing the Noise Generated During Air-Arc Gouging Can Be As Simple As Flipping a Switch

By

George Durkt, Jr.[1]

The Mine Safety and Health Administration (MSHA) has been evaluating the job/task of air-arc gouging performed by mine shop welders. Air-arc gouging is the process of melting an old weld with a carbon based electrode (rod) and blowing the molten metal away with compressed air. Noise levels of 115 dBA or higher can be generated in this process.

Three acoustical field evaluations were conducted at mine shops comparing both Constant Current (CC) and Constant Voltage (CV) techniques for air-arc gouging. The results indicate that by using the CV technique, the average overall A-Weighted Sound Pressure Level (SPL_A) was reduced by as much as 8 dBA from an average of 117.6 dBA to 109.3 dBA. As might be expected, dosimeter results indicated that the rate of noise accumulation was also reduced utilizing the CV technique. The average accumulation rate decreased from 4.5 percent Dose per minute for CC at varying air pressures to 2.0 percent Dose per minute for CV at 80 psig.

INTRODUCTION

The most common technique used in air-arc gouging is to utilize an electric arc welder set for Constant Current (CC) power supply and compressed air ranging between 100 and 110 pounds-force per square inch gauge (psig). Conscientious welders who want to reduce their noise exposure will lower the air pressure by 15-20 psig to between 80-90 psig. This technique has proven to reduce the noise by approximately 3 dBA. However, an alternative technique is to use a Constant Voltage (CV) power supply electric arc welder in conjunction with air pressure no higher than 90 psig. Most large electric arc welders being manufactured today have both types of power supplies built into them as a standard configuration.

The most straightforward definitions for these two types of power supplies are:

> **Constant Current (CC)** – Power supply of the electric arc welder is designed to maintain a **C**onstant **C**urrent as the voltage varies because of the changing arc length.
>
> **Constant Voltage (CV)** – Power supply of the electric arc welder is designed to maintain a **C**onstant **V**oltage as the current varies because of the changing arc length.

MSHA's Program Information Bulletin (PIB) No. P08-12, issued on June 18, 2008, describes technologically achievable, administratively achievable, and promising noise controls for most mining equipment and occupations. The purpose of the PIB is to provide guidance to all mining

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[1] Industrial Hygienist, Physical and Toxic Agents Division, Pittsburgh Safety and Health Technology Center, Pittsburgh, PA.

entities as to what is achievable for noise controls. Currently, MSHA considers the following items as promising noise controls for air-arc gouging. The first is to reduce the air pressure to a minimum. Secondly, select the lowest effective current if utilizing a CC arc welder. Thirdly, select the lowest voltage setting if utilizing a CV arc welder. Finally, utilize alternative gouging rods or other methods to remove the welds such as plasma cutting.

In the Spring of 2004, Safety and Health personnel from Round Mountain Gold Corporation's (RMGC), Smoky Valley Mine located in Round Mountain, Nevada, were invited to MSHA's Headquarters in Arlington, Virginia to present their findings concerning "Reducing Noise Exposure when Air Arcing at RMGC."[2] The results of their study indicated that by combining both a lower air pressure and the use of a Constant Voltage power supply electric arc welder, the sound pressure level of air-arc gouging could be significantly reduced. RMGC indicated that as much as 24 dBA reduction, sound pressure level, was measured from a high of 127 dBA down to a low of 103 dBA. Unfortunately, this noise reduction was the result of measurements collected at the welder's shirt collar location which is, in reality, shielded by the welder's face shield and is not at MSHA's required center-of-shoulder compliance location.[3]

Subsequent to this presentation, personnel from MSHA's Pittsburgh Safety and Health Technology Center (PSHTC) traveled to RMGC's site to conduct their own evaluation. Because of the favorable results from this evaluation, MSHA conducted two other independent field evaluations and the results are presented within this report.

INVESTIGATIVE PROCEDURE

Three separate field evaluations were conducted. The first evaluation was conducted at RMGC and was strictly a controlled diagnostic study with no actual work-shift gouging. The second evaluation involved both a controlled diagnostic study and actual work-shift gouging. The third and final evaluation only involved work-shift comparisons of both gouging techniques.

The controlled diagnostic tests utilized several amperage or voltage settings in combination with varying air pressures while gouging small pieces of scrap steel. The purpose of the tests was to determine if and how these combinations of variables affected the sound pressure level being generated. SPL_A measurements and digital recordings were collected near the welder's ear for each test combination. Each test combination was repeated 3 times, for a total duration of between 1-2 minutes to eliminate any bias and assure valid results. At the same time, other locations within the shop area were also being monitored to determine how the noise being generated was affecting these locations.

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[2] Cottrell, J., Sisson, S., "Reducing Noise Exposures When Air Arcing at RMGC", RMGC Valley View, Vol. III, Issue 9, April 29, 2004, pp. 1-2.

[3] United States Department of Labor – Mine Safety and Health Administration, "Coal Mine Health Inspection Procedures Handbook, Chapter 3, Noise", PH89-V-1 (15) (September 2008), pp. 3-7.

The work-shift gouging tests consisted of collecting acoustical data on both gouging techniques as the company welder performed actual air-arc gouging. Each of the techniques was alternately evaluated after every 1½ to 2 hours and was considered as a work-shift segment. This permitted each technique to be compared directly to the same gouging area. The intent was to eliminate one technique from solely being used on a single area which may have caused the welder to gouge in a unique position or area that could have inadvertently influenced the measurements. The majority of acoustical data collected during this phase was collected with a data logging noise dosimeter. The dosimeter microphone was placed at the welder's center-of-shoulder position, nearest the noise source. In addition to the dosimeter, on-site analysis and digital recordings were also randomly collected near the welder's ear during both techniques as well as at other locations within the shop area.

After the welders were outfitted with the noise dosimeters, they were instructed to begin gouging as they normally would during any other day. Personnel conducting the evaluation monitored the welder(s) as to the time of day (work-shift), which gouging technique was being used and the location on the particular work piece on which the gouging was being performed. This information was documented so it could be correlated with the dosimeter data and digital recordings. Generally, both gouging techniques would be evaluated between 3-4 times during a typical 8-9 hour work-shift. Each time the technique was changed it was considered a test segment. One of the shops had two welders simultaneously gouging the boom of an electric coal shovel that was in for a scheduled rebuild. The other shop had only one welder removing the wear plate from a bulldozer blade which needed replaced. In each shop the welders either climbed onto and/or crawled underneath these structures, demonstrating that in many instances, gouging must be performed in awkward positions and locations.

Figures 1 and 2 are examples of air-arc gouging operations.

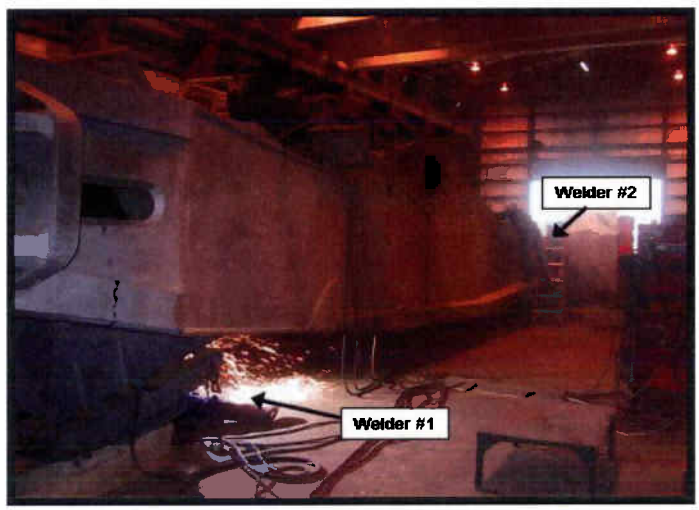

Figure 1. Two Welders Air-Arc Gouging on Coal Shovel Boom

Figure 2. Welder Removing Bulldozer Blade Wear Plates

RESULTS

Table 1 is a list of the final average results from MSHA's diagnostic test evaluation at RMGC and best describes the basis for evaluating the CV technique. The table includes the arithmetic average as well as the plus and minus (±) 1-standard deviation (std), A-Weighted Sound Pressure Level results. It contains the live dosimeter results, the analyzed results from the recordings, both of which were collected at the center-of-right shoulder location, and the average length of time to complete the test gouges. Both the dosimeter and recorded data are being presented within this table to verify that both systems are yielding comparable results.

Table 1. Results of Diagnostic Tests

Center of Right Shoulder Location							
Electric Welder Setting	**Air Pressure In psig**	**Recorded Data In dBA**		**Dosimeter In dBA**		**Gouge Times In Seconds**	
		Avg	**Std**	**Avg**	**Std**	**Avg**	**Std**
720 (CC)	120	116.1	2.5	115.9	3.9	17.3	2.6
600 (CC)	120	112.3	1.9	112.6	2.6	18.5	4.0
500 (CC)	120	111.2	2.1	111.3	2.8	20.0	2.8
400 (CC)	120	110.3	1.9	110.3	2.6	24.0	5.9
35 (CV)	120	106.1	2.6	107.5	3.3	19.4	2.1
Off	120	93.6	0.4	94.5	2.2	15.0	7.1
720 (CC)	110	115.1	1.6	115.0	2.1	14.5	2.4
600 (CC)	110	112.3	0.6	112.2	0.9	19.0	4.4
500 (CC)	110	111.4	2.5	111.6	3.5	19.8	4.8
400 (CC)	110	110.1	1.0	109.8	1.4	22.0	5.2
35 (CV)	110	105.6	2.7	106.1	2.7	18.6	1.9
Off	110	93.9	1.0	95.0	3.2	15.0	7.1
720 (CC)	100	114.0	1.5	114.1	2.5	15.5	3.0
600 (CC)	100	112.0	1.6	112.5	1.8	19.3	3.4
500 (CC)	100	111.4	0.9	111.4	1.6	20.5	3.7
400 (CC)	100	110.1	1.0	109.6	1.7	22.8	4.1
35 (CV)	100	106.7	0.4	107.0	0.6	19.5	2.4
Off	100	93.8	2.0	95.3	3.5	15.0	7.1
720 (CC)	90	114.4	1.9	114.0	2.5	16.0	2.4
600 (CC)	90	111.6	1.4	112.3	2.3	19.0	3.4
500 (CC)	90	111.1	1.6	111.2	2.2	21.0	4.1
400 (CC)	90	109.3	1.0	109.1	1.8	21.3	5.4
35 (CV)	90	105.3	2.5	106.0	2.1	18.5	1.9
Off	90	93.7	1.5	94.6	3.0	15.0	5.8
720 (CC)	0	100.3	-	98.4	-	9.0	-
600 (CC)	0	94.8	-	94.0	-	11.0	-
500 (CC)	0	89.8	-	NA	-	10.0	-
400 (CC)	0	85.7	-	NA	-	14.0	-
35 (CV)	0	89.6	-	NA	-	12.0	-

The table contains five data groups which are arranged in descending order by the tested air pressures, from 120 psig to 0 psig (second column). The first four sections are the results of the combined psig air pressure and electric arc welder settings. The last section is the results where an arc is struck without any psig air pressure. Within each psig air pressure group are the six electric arc welder settings.

The first four are the CC settings. The fifth is the CV setting and the sixth setting was air pressure alone without gouging.

The three obvious points from the table are:

1. The SPL_A values within each air pressure group decreases as the electric arc welder's amperage is decreased.
2. The SPL_A value for the CV setting is always significantly less than any CC result within that air pressure group, and
3. Other than the 720 amperage variable results, there are no significant differences among the other variables and air pressures.

Similar results were obtained during the second location's evaluation. When both sets of values are combined the results yield an SPL_A reduction of 8.3 ± 2.5 dBA from a high of 117.6 dBA, for CC setting at air pressures of over 100 psi, down to a low of 109.3 ± 8.9 dBA for CV setting at approximately 90 psi air pressure.

Results from the first diagnostic evaluation are more clearly represented in Figure 3.

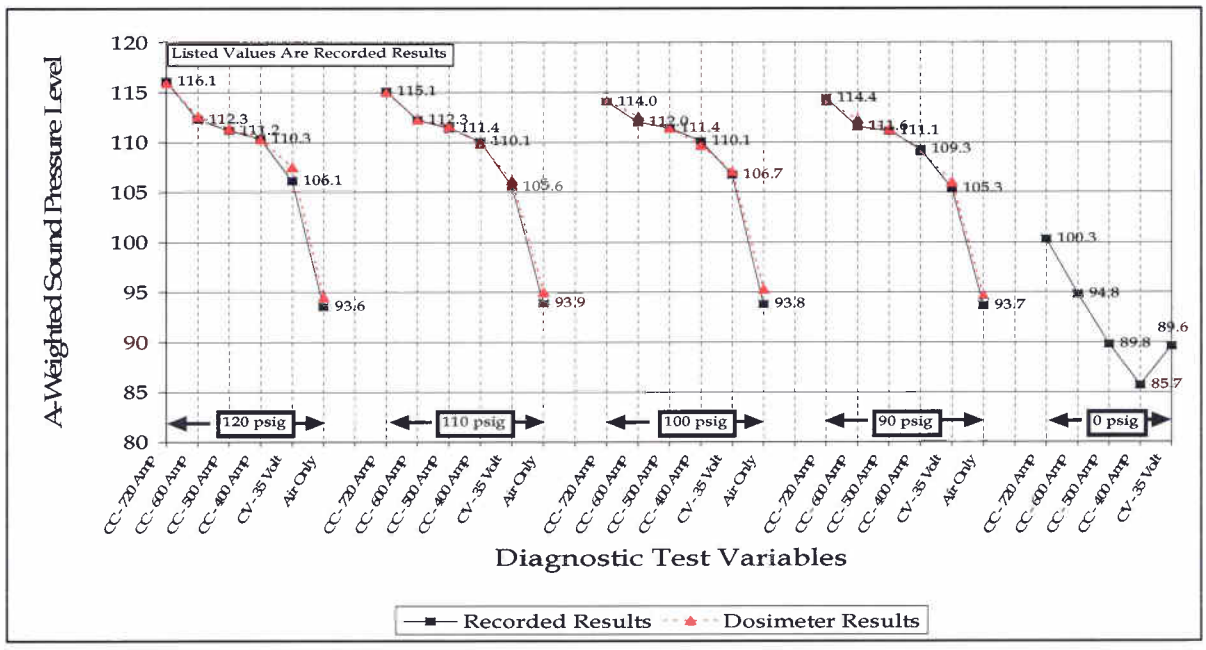

Figure 3. Diagnostic Test Results at RMGC

The figure clearly indicates the SPL_A values decrease as amperage decreases within each psig air pressure group. The figure also indicates that the CV setting of 35 Volts produces a significantly less SPL_A result than any of the CC settings. Other than the CC-720 amp values there is virtually no difference between similar arc welder settings among the air pressure groups; for example, comparing all of the CC-400 amp results yields values of 110.3 dBA, 110.1 dBA, 110.1 dBA and 109.3 dBA among the air pressures. The "air only" results are included to indicate an expected minimal noise level the welders would be exposed to without the electrical arcing of the gouging rod. Notice there is virtually no difference in SPL_A results between the air pressures. It is suspected that the lack of sound pressure difference is a result of collecting the measurement as the welder was releasing the air over a smooth section of steel instead of a previously gouged section. Had this test been conducted on a gouged section, the raggedness of the cut would have caused the compressed air to form vortices in this area and increase the sound pressure, or at least cause each to be distinguishable among each other.

The final section of the figure plots the results of creating the electrical arc between the rod and steel plate without the use of air under pressure to blow the molten metal away. It is interesting to see that there is a nearly consistent or linear reduction of 5.0 dBA, for each lowered amperage setting, until the CV-35 volt sample, when the results increase.

Figure 4 depicts the average amounts of time to complete the gouge at each test variable. It also clearly shows that as the electric arc welder's amperage decreases, the amount of time to complete the test gouge increases slightly, in terms of seconds. This slight increase in time is not considered to negatively impact the welder's noise exposure. The figure also shows that for the 35 Volt CV setting, the gouge time is nearly equal to the gouge time of the 500-600 amperage CC settings. The ± 1 std bars are included to show that the times varied between 2.0 and 6.0 seconds but were not noticeable or considered excessive to the welder.

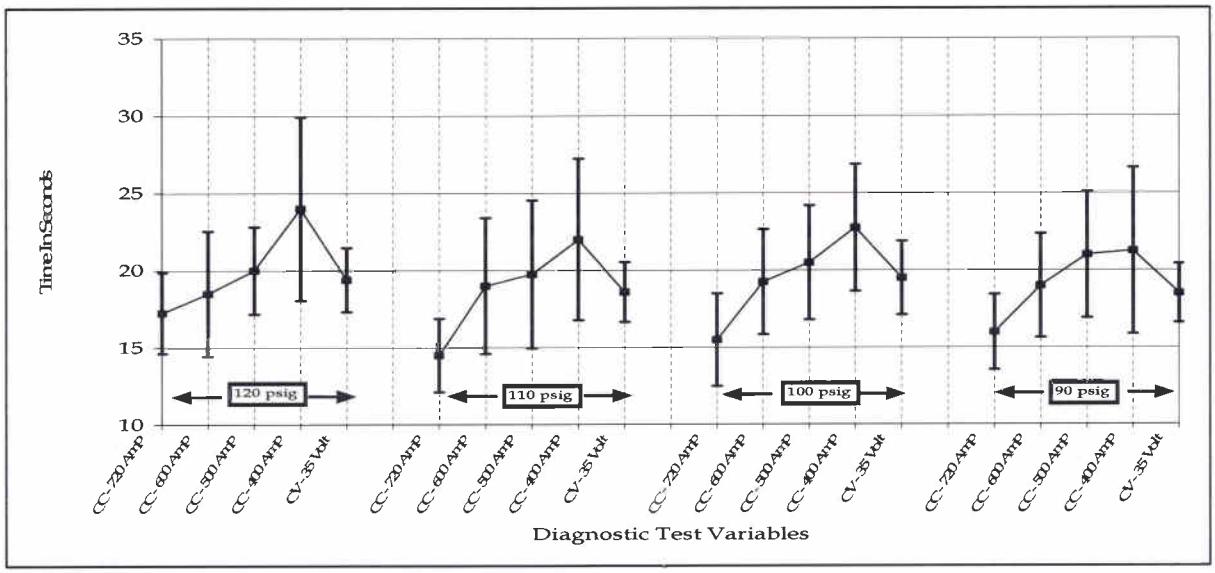

Figure 4. Gouge Times of Diagnostic Tests

The results from the first work-shift evaluation are summarized in Figure 5. This figure represents the cumulative noise exposure results, from a dosimeter, for one of the company welders while gouging the coal shovel boom. The figure is separated into four segments. There are two CC technique segments (#1 and #3), and two CV technique segments (#2 and #4). As the welder is subjected to noise, his noise exposure begins to add cumulatively. Intense and continuous noise causes a fast increase in cumulative dose, which is represented by steeply increasing plots. Less intense noises are represented as slowly increasing plots.

Visually evident from Figure 5 is that the CC segments increase more quickly than the CV segments. Within each segment is an arrowed line that represents the slope of the accumulated noise. Next to this arrowed line is the calculated value for the amount of noise, in percent Dose, being accumulated for each minute of time, (% Dose/minute). Both CC segments increase at a rate of 5.5 % Dose/minute. The first CV segment increases at 2.6 % Dose /minute and the second segment at 1.5 % Dose/minute.

For analytical purposes the two CV segments were arithmetically averaged to yield a 2.1 % Dose/minute accumulation value which is slightly less than one-half of the CC accumulation.

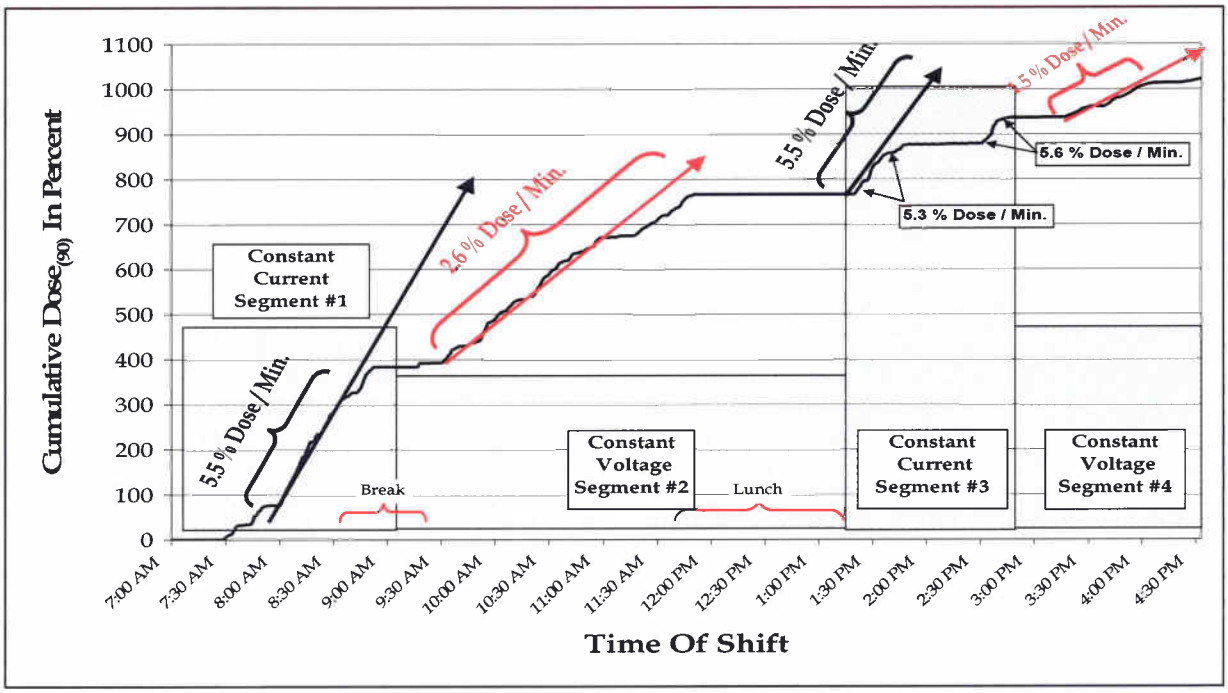

Figure 5. Cumulative Work Shift Noise Exposure Results from Work-Shift Location #2

What these values suggest is that, during the period of time the CV-90 psig technique is being utilized, the welder can expect to decrease his noise exposure by almost one-half, when compared to the CC-90 psig technique.

To illustrate how these results affect the noise exposure of the welder, Figure 6 was constructed using the two calculated accumulation rates from the previous figure as a model of what can be expected. It contains three cumulative dosimeter plots. The dashed plot is the actual dosimeter data collected during the work-shift evaluation as the two techniques were being evaluated. The solid black plot is the CC model using the 5.5 % Dose/minute accumulation factor and the solid red plot is the CV model using the 2.1 % Dose/minute accumulation factor.

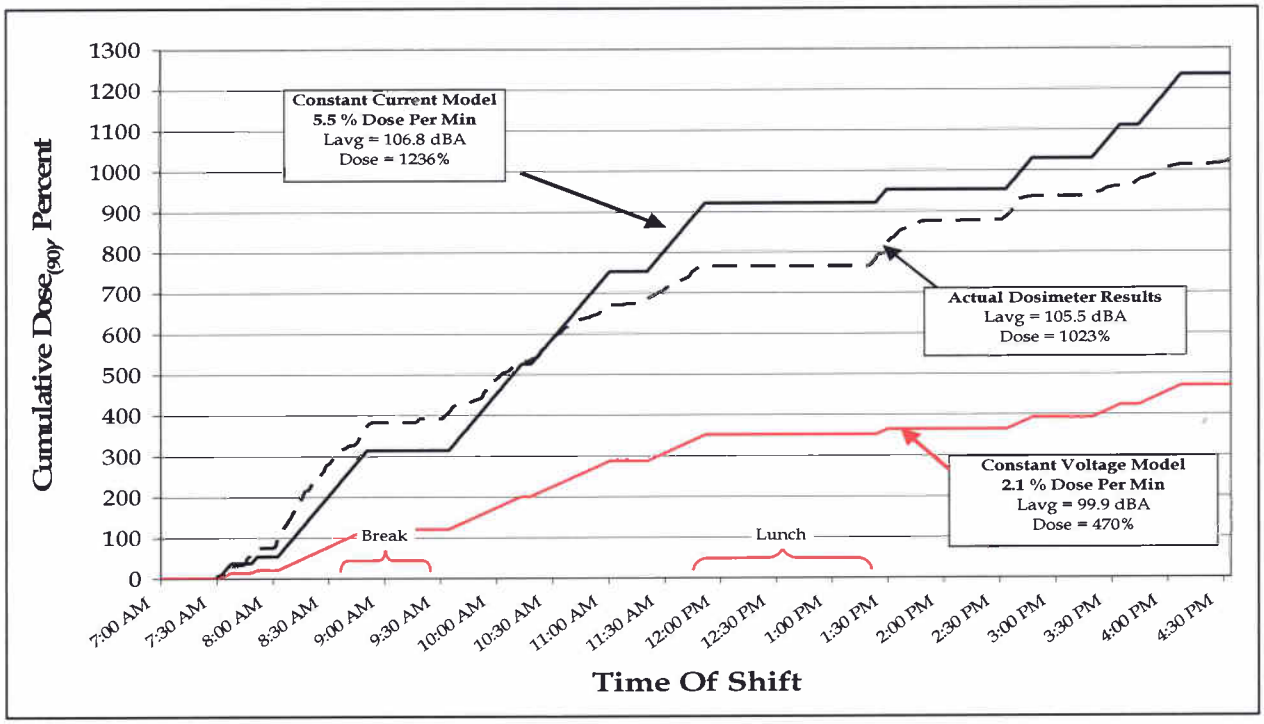

Figure 6. Model Results Based on Work-Shift Location #2 Data

The figure clearly indicates the noise exposure accumulation rate is significantly lower for the CV air-arc gouging technique. At the end of the shift the welder's noise exposure would have been reduced by more than one-half from 1236 % Dose to 470 % Dose. This also represents a 6.9 dBA average reduction in noise exposure (106.9 dBA vs. 99.9 dBA) during the work shift. MSHA considers a 3.0 dBA average reduction in equivalent noise exposure as significant.

The third and final field evaluation comparing both gouging techniques is summarized in the following figures. Figure 7 shows the 1-minute SPL_A values as collected by the data logging dosimeter worn by the welder during the first day of the evaluation. Again, it visually indicates the SPL_A generated during a CC gouge is significantly higher than the CV technique SPL_A.

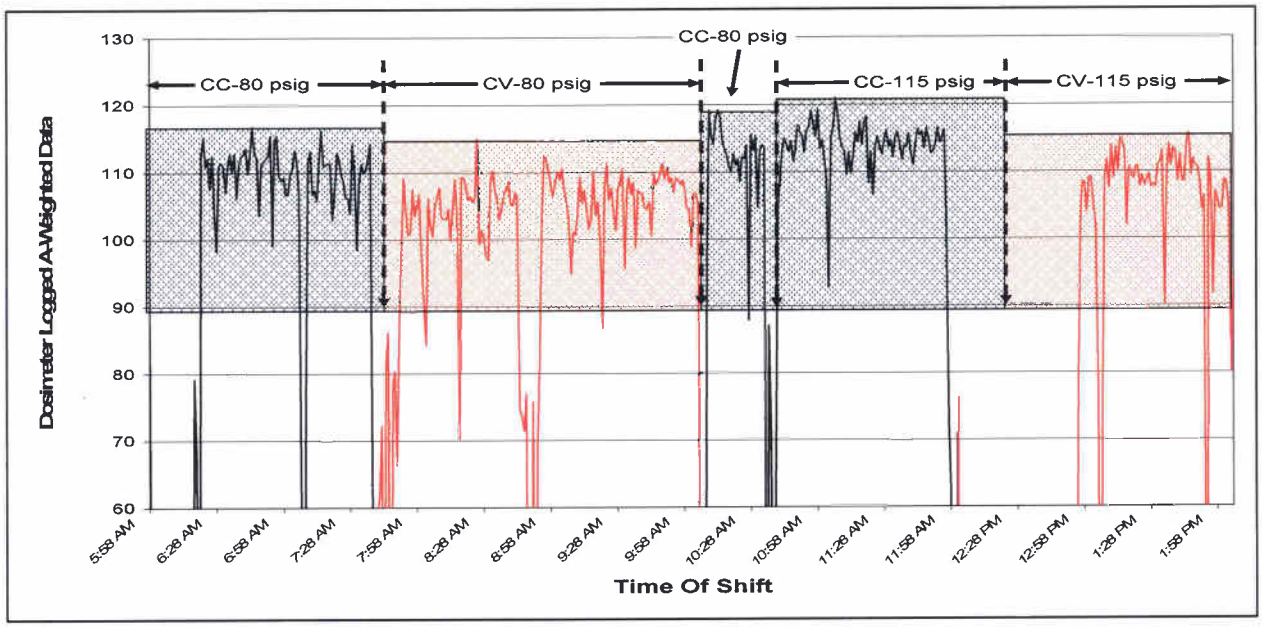

Figure 7. Work-Shift SPL_a Results Collected During Third Field Evaluation

To assist in the explanation, semi-transparent boxes have been included within each segment. These boxes encompass all data within 90 dBA and the maximum level for that test segment. Ninety (90) dBA was chosen because it represents the Criterion Level (CL) of the MSHA Standard.

The figure also clearly shows that when 115 psig air pressure was evaluated at both the CC and CV technique, the CC technique's SPL_A values increased (visually apparent when compared to the 80 psig results).

Using the same technique as was used in Figures 5 and 6, a rate of accumulation of 1.8 % Dose per minute was calculated for the second test segment (CV-80 psig) shown in Figure 7. This value was used to construct Figure 8, which plots both the actual noise exposure for the welder during the evaluation and the projected results based on the 1.8 % Dose/minute value. Within each test segment of the actual noise exposure plot are the calculated accumulation rates for the remaining segments.

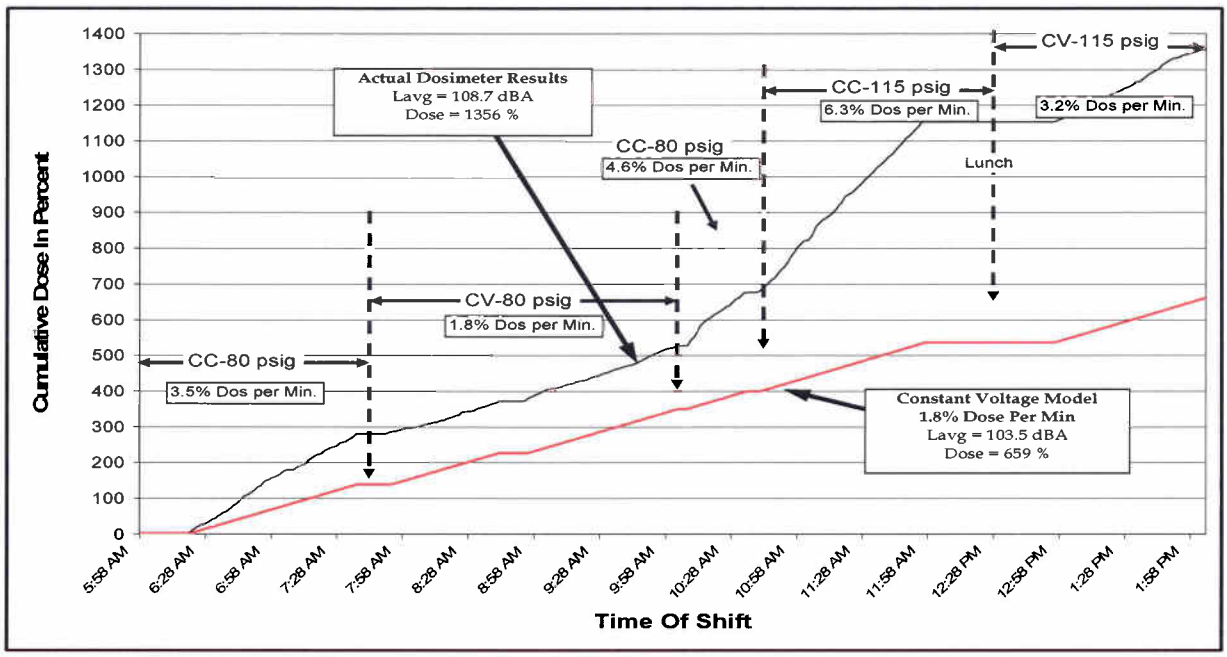

Figure 8. Theoretical Model Results Based On 1.8 % Dose/Minute Accumulation

Figure 8 clearly shows how the different variables affect the rates of Dose accumulation. In this example, the welder's noise exposure would have been reduced by 697% Dose, from 1326% to 659% Dose. This represents a 5.2 dBA reduction in equivalent noise exposure (108.7 dBA vs. 103.5 dBA). A minimum of 10 individual work-shift segments were collected for each technique during the two evaluations.

When all of these work-shift segments were combined, they yielded an average Dose/minute accumulation of 4.49 ±1.26, for all CC results and 1.95 ± 0.66 for all CV settings at air pressures below 100 psig.

Figure 9 compares the wave forms of both gouging techniques as they were recorded during the evaluation. It again visually shows how both techniques appear on an amplitude and time scale. The two obvious differences are in the amplitude (loudness) and the jaggedness or smoothness of the wave form. The CV-80 psig wave form displays significantly less amplitude and appears more "smooth or uniform," indicating that the sound being generated is constant. The CC-80 psig wave form is more erratic indicating the sound being generated is both louder and consists of multiple mini-impulse fluctuations during its generation. These mini-impulses are actually the electric arc being generated between the metal surface and the gouging rod as the air is being blown over the molten metal. The figure clearly shows the CV technique can maintain a more consistent/uniform arc as opposed to the CC techniques.

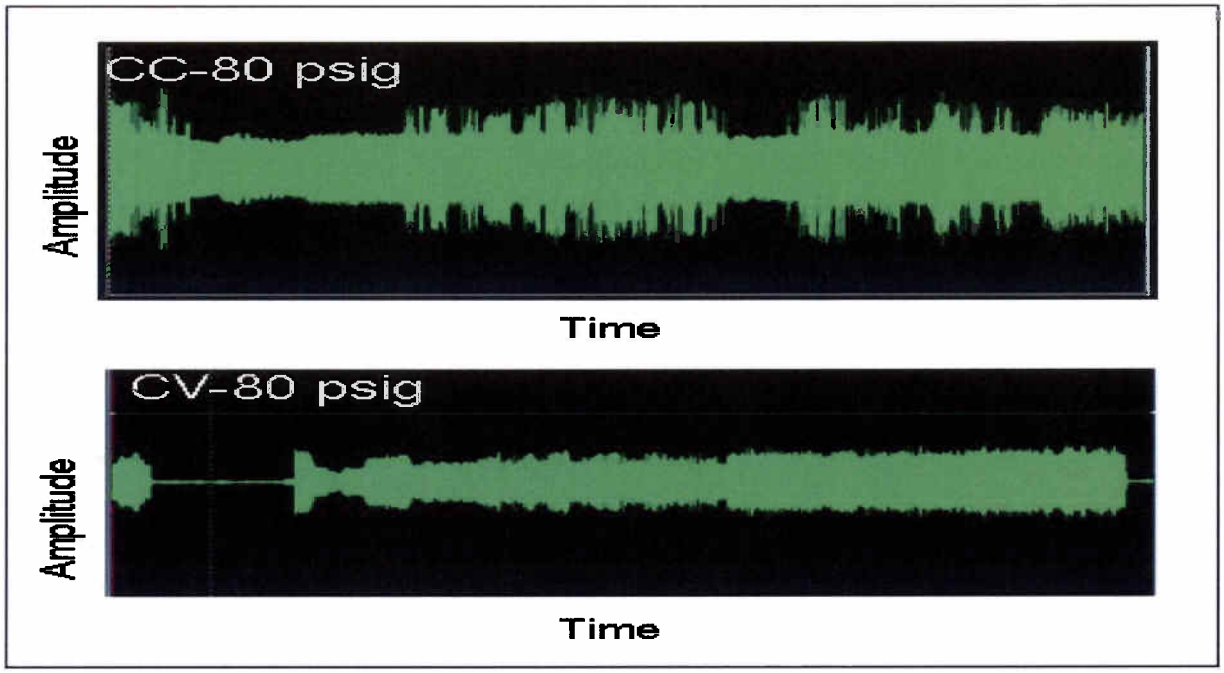

Figure 9. Wave Form Comparison of Both Gouging Techniques

The difference in sound pressure level between the CC and the CV techniques can also benefit other workers within the shop area. Figure 10 depicts the measurement locations within the shop building to access how the noise being generated in the gouging area is affecting the other areas of the shop. As the gouging evaluation was being conducted, simultaneous measurements were collected within each of the five bays as denoted in the figure. The area measurements in bay #5 were collected approximately 30 feet away from the welder as he gouged. The remaining measurements were collected at a similar location within each successive bay.

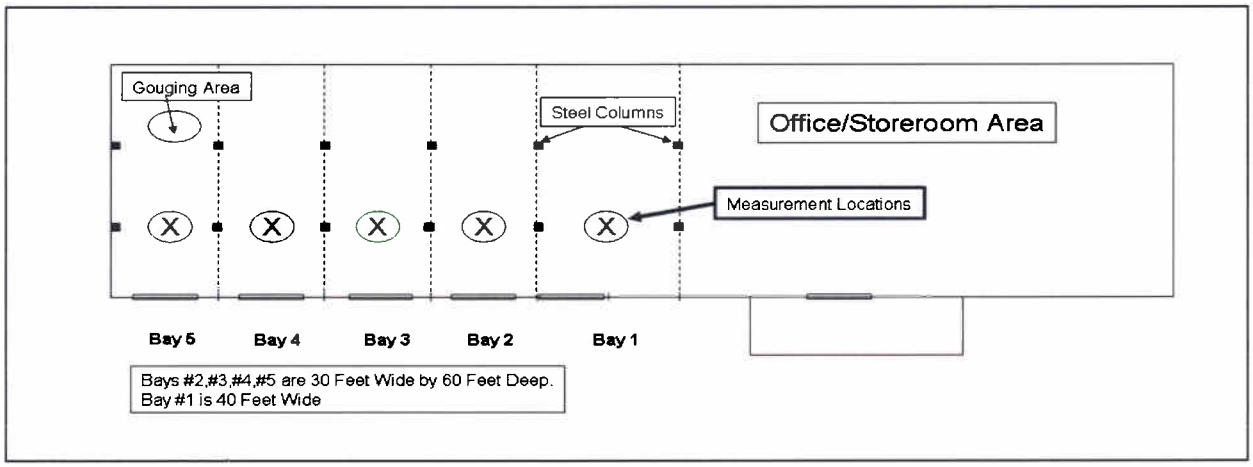

Figure 10. Measurement Locations within the Shop Area

Figure 11 plots the SPL_A results that were measured in each of 5 bays. The results verify that as the welder is gouging with the CV-80 psig technique, other areas of the shop are experiencing a decrease in the SPL_A as well. In every location measured, the CV-80 psig results were consistently lower. In fact, as soon as the welder began gouging with the CV-80 psig technique, other personnel within the shop building came over and commented on the "noticeable" difference in loudness.

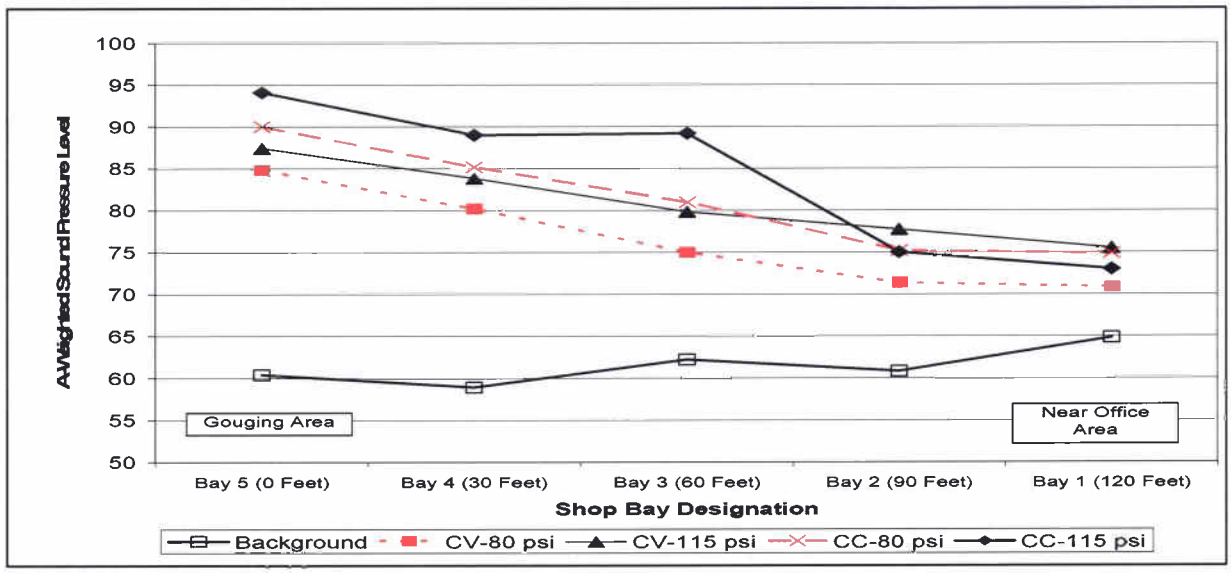

Figure 11. Average SPL_a Results within the Shop Building

After the welders and other company personnel witnessed the difference in noise being generated with the CV technique, the most asked question was, "Why is the CV technique quieter"? It is believed the major explanation lies within the CV power supply of the electric welder.

One of the main requirements for any person welding is to maintain a proper arc length to assure a good weld. The arc length, which is controlled by the operator's hand, affects the electric arc welder's ability to control two aspects. The first is the arc voltage and second is the arc current. Both of these aspects are automatically controlled within the electric arc welder by its internal electronics which are inherently different for CC and CV power supplies. Today's electric arc welders are manufactured with sophisticated electronics such as power inverters and computer programmable features already incorporated into them. This allows for various types of metals with different characteristics to be welded using a single electric arc welder. The majority of large electric arc welding machines being manufactured today have both the CC and CV power supplies incorporated into them as a standard feature because of the need to weld varying metals.

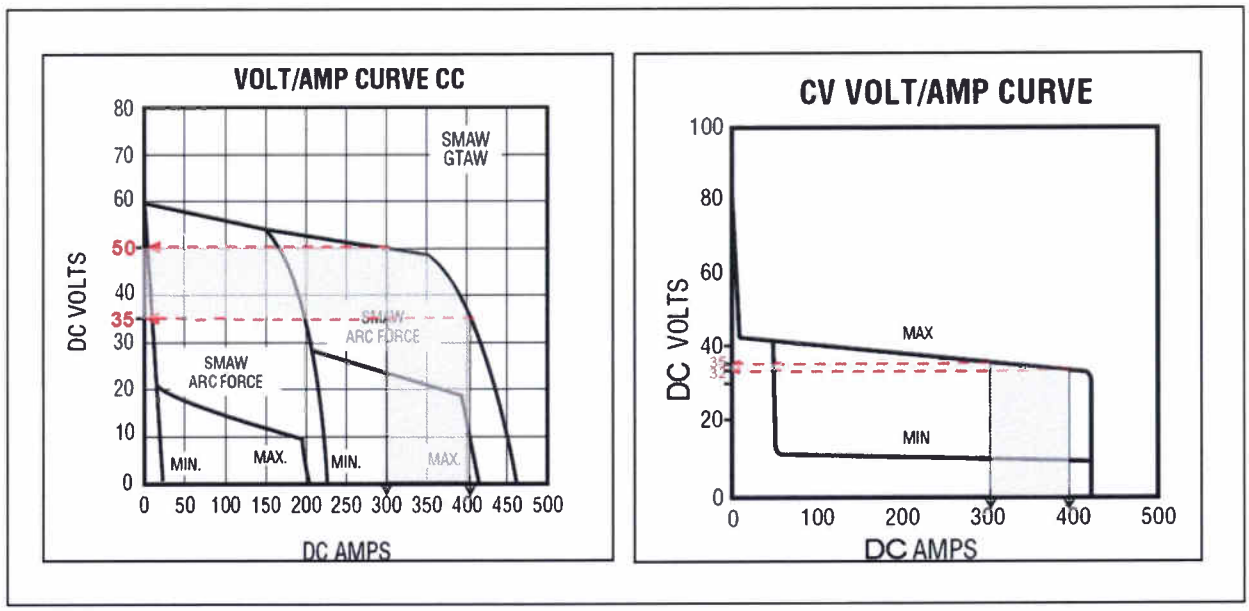

Figure 12. Sample Volt-Amp Curve for a Combination CC and CV Welding Machine

Figure 12 is a voltage-ampere (volt-amp) curve of a commercial electric welder that has both CC and CV capabilities. The CC curve on the left is sometimes referred to as a "dooper" because the curve sharply decreases as amperage increases. Therefore, large changes in arc voltage will cause only small changes in welding current, thus its name, "constant current." The curve to the right is typical of CV power supplies. It is characterized by yielding small changes in the arc voltage while having large changes in the welding current. They tend to keep the output voltage constant while varying the current, thus its name, "constant voltage." They are considered to be self regulating.[4]

Included in the figure are several shaded areas representing a recommended amperage range of between 300-400 amps for typical gouging rods. The corresponding voltage levels are also shaded and noted with arrows and values. For the CC curve these voltage values are between 35-50 DC volts and the CV curve's values are between 32-35 DC volts. In this example, the CV power supply would be supplying a maximum of 35 volts as compared to a maximum 50 volts for the CC power supply. This decrease in voltage can be translated into a decrease in power or watts, which in acoustical terms can be interpreted as "less power" generates "less sound pressure."

CONCLUSION / DISCUSSION

Based on the results from these three evaluations, it is evident that by using the CV technique and air pressures between 80 to 90 psig, for air-arc gouging, it is possible for welders and other employees nearby to lower their full-shift noise exposure. It appears that the CV power supplies being manufactured today have the capability of maintaining or adjusting the output current more

[4] Armao, F., "AL GMAC: CC or CV?", Practical Welding Today, June 12, 2003, http//www.thefabricator.com/AluminumWelding/AluminumWelding_Article.cfm?,ID=613

efficiently and using a lower voltage. Because of this lower voltage the arc that is generated between the gouging rod and metal is of a lower wattage and potentially less generated sound pressure. In addition to less sound pressure generation, the CV power supplies electronics does not cause the voltage or current to fluctuate as violently as displayed in Figure 9 when comparing the wave forms. The results also demonstrate that other miners within the shop areas benefit from the noise reduction.

The CV technique did not significantly increase the gouging times. One welder suggested the CV technique appeared quicker because the arc generated was more consistent and therefore easier to handle.

Based on conversations with several electric arc welding machine manufacturers the technique of using a CV power supply for air-arc gouging to reduce the noise exposure of the welder was not known.[5,6] CV power supplies have been recommended as an alternative for certain types of welding and even air-arc gouging; however, noise reduction was never the intended benefit. These manufacturers have agreed that the reduction in noise or sound pressure is probably due to the lower power.

This evaluation has shown that the sound generated during air-arc gouging can be significantly reduced if a CV power supply electric welder is used in conjunction with a lower air pressure. Further research into these power supplies should be initiated to investigate if additional noise reduction can be gained not only for gouging, but possibly for welding.

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[5]The Lincoln Electric Company, 22801 St. Clair Ave., Cleveland, Ohio, January 22, 2009, www.lincolnelectric.com

[6]Miller Electric Manufacturing Co.,1635 West Spencer Street, Appleton, Wisconsin, February 5, 2009, www.MillerWelds.com