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An American National Standard

Recommended Practices for
Air Carbon Arc Gouging and Cutting



American Welding Society

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Recommended Practices **for Air Carbon Arc** **Gouging and Cutting**

Supersedes C5.3-82

Prepared by
AWS Committee on Arc Welding and Cutting

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors

Abstract

This publication establishes a method of conveying to the welder/operator the proper setup and use of air carbon arc gouging and cutting. Instructions and procedures are supplied in detail so the welder/operator can establish the correct air pressure, amperage, voltage and techniques.



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Foreword

(This Foreword is not a part of ANSI/AWS C5.3-91, *Recommended Practices for Air Carbon Arc Gouging and Cutting*, but is included for information purposes only.)

These recommended practices have been prepared by Subcommittee C5K on Air Carbon Arc Cutting, of the AWS Arc Welding and Cutting Committee. It is important to recognize that this publication does not present the only possible conditions for using the air carbon arc cutting process. The data given are presented merely as guides in establishing operating conditions.

Subcommittee C5K will welcome comments on these recommended practices, as well as any additional information on the air carbon arc process that could be included in a subsequent revision. Communications should be addressed to the Secretary, AWS Arc Welding and Cutting Committee, American Welding Society, 550 LeJeune Road, P.O. Box 351040, Miami, FL 33135.

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Recommended Practices for Air Carbon Arc Gouging and Cutting

1. Scope and Description

This publication presents the basic concepts of the air carbon arc (CAC-A)¹ cutting process to provide a fundamental understanding of the process and its variables. In addition, specific technical data are presented as a guide in establishing optimum operation of this process.

1.1 Description. Air carbon arc cutting (CAC-A) is a physical means of metal removal in contrast to the oxidation reaction in oxyfuel gas cutting (OFC). In the air carbon arc cutting process, the intense heat of the arc between the carbon electrode and the workpiece melts a portion of the workpiece. Simultaneously, a jet of air is passed through the arc of sufficient volume and velocity to blow away the molten material. The exposed solid metal is then melted by the heat of the arc, and the sequence continues. Air carbon arc cutting does not depend on oxidation to maintain the cut, so it is capable of cutting metals that OFC will not cut. The process is used successfully on carbon steel, stainless steel, many copper alloys, and cast irons. The melting rate is a function of current. The metal removal rate is dependent upon the melting rate and the efficiency of the air jet in removing the molten metal. The air must be capable of lifting the molten metal out and clear of the arc region before resolidification.

1.2 History. Air carbon arc cutting was developed in the 1940's as an extension of an existing process—carbon arc cutting. Faced with the removal in the flat position of several hundred feet of cracked stainless steel weld, a welding engineer developed air carbon arc cutting. Carbon arc cutting was used to remove defective welds and rivet heads, but only in the overhead and vertical positions. The carbon arc melted the metal and gravity moved the molten metal out of the area. It was reasoned that an air jet could provide the force to remove the metal in the flat position. A direct current electrode negative carbon arc was tried, and an air blast was

provided by the second cutter with an air nozzle directed at the pool. This attempt was not very successful because the arc was not stable. Direct current electrode positive was tried, and the result made air carbon arc cutting practical. The basic principle remains the same today, but the equipment and applications have been improved and expanded.

In 1948, the first air carbon arc torch was introduced to the welding industry. No longer were two cutters needed. The air was fed through the torch and out beneath the electrode at the correct location. This new tool was found to save time on backgouging of welds and removal of cracks and other weld defects on carbon, alloy, and stainless steels. Previously, this type of work had been done by grinding or chipping. As the use of the air carbon arc cutting expanded, torches were designed for more efficient and cleaner metal removal and for cutter comfort.

1.3 Applications. The air carbon arc cutting process is used throughout industry in a variety of applications, such as metal fabrication and casting finishing, chemical and petroleum technology, construction, mining, general repair and maintenance. CAC-A torches and electrodes are used to create groove weld preparations in plates butted together. Little or no additional cleaning or grinding is needed. The CAC-A process can then be used to backgouge the joint to sound metal to assure complete joint penetration. If during welding a problem arises and an area of the weld does not meet specifications, the air carbon arc cutting process can be used to remove the defective weld metal without damaging or detrimentally affecting the base metal. The air carbon arc cutting process is used in the foundry industry to remove fins and risers from castings and then used to wash the contact areas off smooth with the surface in preparation for shipment of the casting. The air carbon arc process presents great flexibility, efficiency, and cost effectiveness when applied to practically any type of metal. Carbon steel, stainless steel, gray, malleable, and ductile iron, aluminum, nickel, copper alloys and other non-ferrous metals can be worked on with CAC-A.

1. CAC-A (Carbon Arc Cutting-Air) was formerly AAC (Air Arc Cutting)

2. Fundamentals of the Process

2.1 General. CAC-A requires an arc to develop a molten pool on the workpiece. Compressed air is introduced to blow away this molten metal.

The process requires a welding power source, a source of compressed air, carbon electrode, and cutting torch. Figure 1 shows the typical arrangement for using this process.

Except for special applications discussed later, CAC-A is used with DCEP (reverse polarity). The electrode should have a maximum extension of 7 inches from the cutting torch, with the air jet between the electrode and the workpiece. Although there is no minimum extension, care should be taken to prevent damage to the torch. Therefore 1-1/2" to 2" minimum extension is recommended. Progression should only be in the direction of air flow. The electrode push angle will vary, depending on the operation being performed. The cutter should maintain the correct arc length to allow the air jet to properly remove the molten metal. See Figure 2.

2.2 Power Sources. Single phase machines with low open circuit voltage are generally inadequate for CAC-A. However, any three phase welding power source of

sufficient capacity may be used provided the manufacturer recommends its use for CAC-A. The open-circuit voltage must be sufficiently higher than the required arc voltage to allow for voltage drop in the circuit. The arc voltage used in air carbon arc gouging and cutting ranges from 35 to 56 volts (V); thus the open-circuit voltage should be at least 60 V. The actual arc voltage in air carbon arc gouging and cutting is governed to a large extent by arc length and the application.

2.3 Compressed Air. Standard compressed air is satisfactory for air carbon arc cutting. Between 80 psi (413.7) and 100 psi (690) pressures at the torch are normally used. Higher pressures may be used, but offer little advantage in metal removal efficiency. Pressures as low as 40 psi (280 kPa) have been used with some manual torches in field applications where only cylinders of compressed air are available. However, pressures this low are not recommended. Regardless of the pressure used with manual torches, the air hose supplying the concentric cable assembly should have a minimum inside diameter (ID) of 3/8 inch. Mechanized torches with automatic arc length control should have an air supply hose with minimum ID of 1/2 inch. Table 1 gives the consumption rate of compressed air for the various types

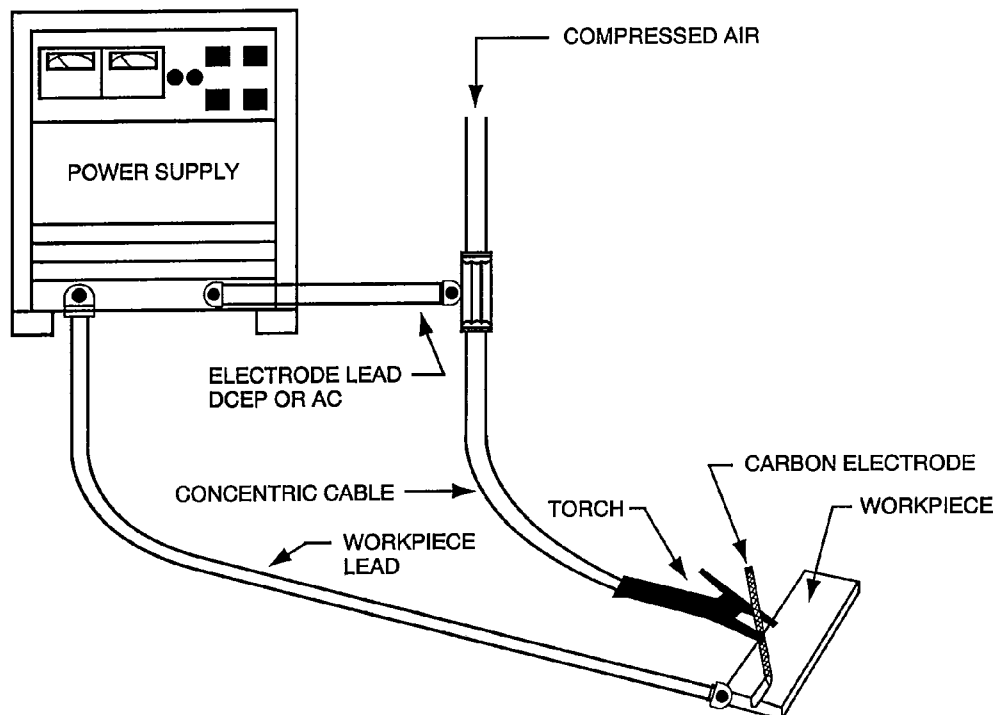
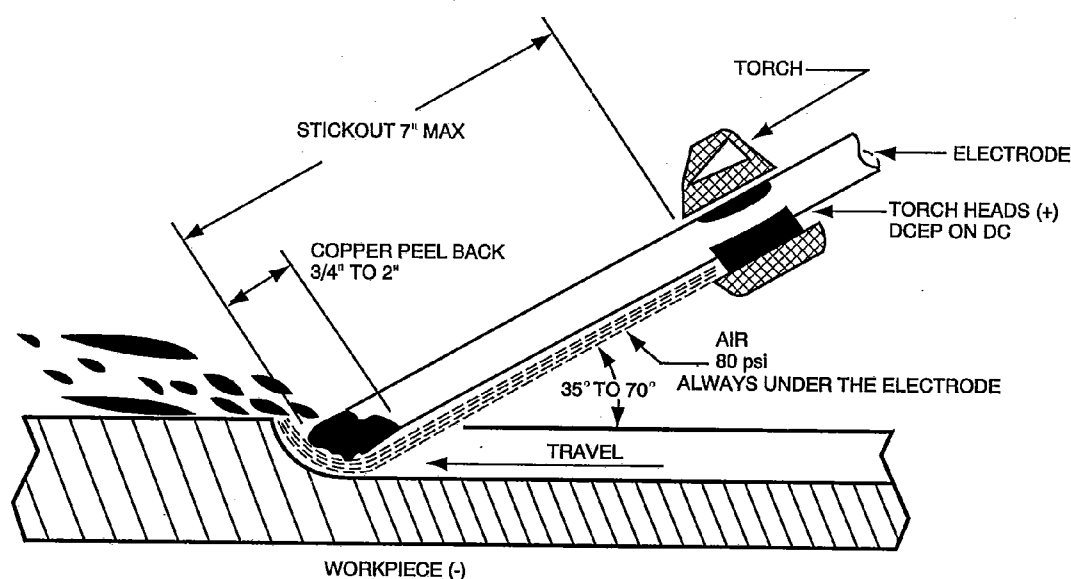


Figure 1 — Typical Arrangement for the Air Carbon Arc Cutting Process



1. GENERAL PURPOSE HEADS ON FOUNDRY TORCHES HAVE AIR ON BOTH SIDES.

Figure 2—How a Standard CAC-A Torch Works

Table 1
Recommended Minimum Air Requirements

Type of Torch	Air Pressure psi ¹	Air Consumption cfm	Compressor Rating		ASME Receiver Size (gal.)
			Intermittent Use	Continuous Use	
Light Duty ²	49	8	0.5 hp	1.5 hp	60
General Duty ²	80	25	5 hp	7.5 hp	80
Heavy Duty ³	80	33	7.5 hp	10 hp	80
Automatic ⁴	60	46		15 hp	80

Notes:

1. Pressure while cutting.
2. Accommodates flat electrodes.
3. Generally considered a foundry torch.
4. Requires a mechanical travel system for the torch or workpiece.

of manual and mechanized torches as well as the compressor power rating required for intermittent and continuous use. Compressors shall have a standard receiver tank for the compressor rating.

2.4 Electrodes. There are three basic types of electrodes:

2.4.1 DC Copper Coated Electrodes. This type is most widely used because of its comparatively long electrode life, stable arc characteristics, and groove uniformity. These electrodes are made from a special mixture of

carbon and graphite with a suitable binder. Baking this mixture at the appropriate temperature produces dense, homogeneous graphite electrodes of low electrical resistance which are then coated with a controlled thickness of copper. These electrodes are available in the following diameters: 1/8", 1/4", 1/2", 5/32", 5/16", 5/8", 3/16", 3/8", and 3/4".

Jointed electrodes are available for operation without stub loss. They are furnished with a female socket and a matching male tenon, and are available in the following diameters: 5/16", 5/8", 3/8", 3/4", 1/2", and 1".

In addition to cylindrical electrodes, there are flat (rectangular) coated electrodes in the following sizes: $5/32" \times 3/8"$ and $3/16" \times 5/8"$. These are used for making rectangular grooves and for the removal of weld reinforcements.

2.4.2 DC Plain Electrodes. Of limited use, these electrodes are generally used in diameters of less than $3/8$ inch (9.5 mm). During cutting these electrodes are consumed more rapidly than the coated electrodes. They are manufactured the same as the coated electrodes without the copper coating. Plain electrodes are available in the following diameters: $1/8"$, $1/4"$, $1/2"$, $5/32"$, $5/16"$, $5/8"$, $3/16"$, $3/8"$, $3/4"$, and $1"$.

2.4.3 AC Coated Electrodes. The following electrodes are made from a special mixture of carbon and graphite with a suitable binder. Rare-earth materials are incorporated to provide arc stabilization for cutting with an alternating current. These electrodes, coated with a controlled thickness of copper, are available in the following diameters: $3/16"$, $3/8"$, $1/4"$, and $1/2"$.

2.5 Cutting Leads. Table 2 gives the recommended number and sizes of cutting leads for different currents and lengths.

2.6 Manual Cutting Torches. A typical manual torch is shown in Figure 3. The electrode is held in a rotating head which contains one or more air orifices, so that,

regardless of the angle at which the electrode is set with respect to the cutting torch, the air jet remains in alignment with the electrode. Cutting torches with two heads (the air jet is on two sides of the electrode) or with a fixed angle between the electrode and the holder, are preferred by some users for special applications. Normally, cutting torches are air cooled. For high current applications, water-cooled cable assemblies are available and may be used with heavy duty torches.

2.7 Mechanized Cutting Torches. There are two methods of controlling mechanized air carbon arc cutting torches. Either system is capable of making grooves of consistent depth to a tolerance of ± 0.025 inch. These units are used where high quality, high productivity, or gouges in excess of 3 feet long are desired (see Figure 4). They are as follows:

2.7.1 An amperage-controlled type which maintains the arc current by amperage signals through solid state controls. This type of system controls the electrode feed speed, which maintains the preset amperage and can be operated with constant potential power sources only.

2.7.2 A voltage-controlled type which maintains arc length by voltage signals through solid state electronic controls. This type controls the arc length determined by the preset voltage, and can be used with constant current power supplies only.

Table 2
Recommended Number and Size of Cutting Leads for Various Currents^{1,2} and Lengths^{3,4}

Current (Amperes)	25 feet		50 feet		100 feet		150 feet		200 feet		250 feet	
	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size	No.	Size
100	1	4	1	3	1	2	1	1/0	1	2/0	1	4/0
200	1	3	1	2	1	1/0	1	3/0	1	3/0	3	3/0
300	1	2	1	2	1	3/0	2	2.0	2	4/0	4	4/0
400	1	2	1	1/0	1	4/0	2	4/0	3	4/0	5	4/0
500	1	1	1	2/0	2	2/0	2	4/0	4	4/0		
600	1	1	1	3/0	2	3/0	2	4/0	5	4/0		
800	1	1/0	2	2/0	2	4/0	4	4/0				
1000	1	2/0	1	4/0	3	3/0	5	4/0				
1200	1	3/0	2	4/0	3	4/0						
1400	1	4/0	2	4/0	4	3/0						
1600 ⁵	2	3/0	4	3/0	4	4/0						
1800	2	4/0	4	4/0								
2000 ⁶	3	4/0	5	4/0								

Notes:

1. Recommendations based on 4 V, DC loss/100 feet.
2. For AC use next higher size of cable.
3. Length given is one half the sum of the electrode and the workpiece leads.
4. Improper ground connection causes cable overheating; at least 1 inch of contact area should be used. Be sure the connection is tight.
5. Over 1600 amps, a heavy duty air-cooled cable should be used.
6. Over 2000 amps, a heavy duty water-cooled cable must be used.

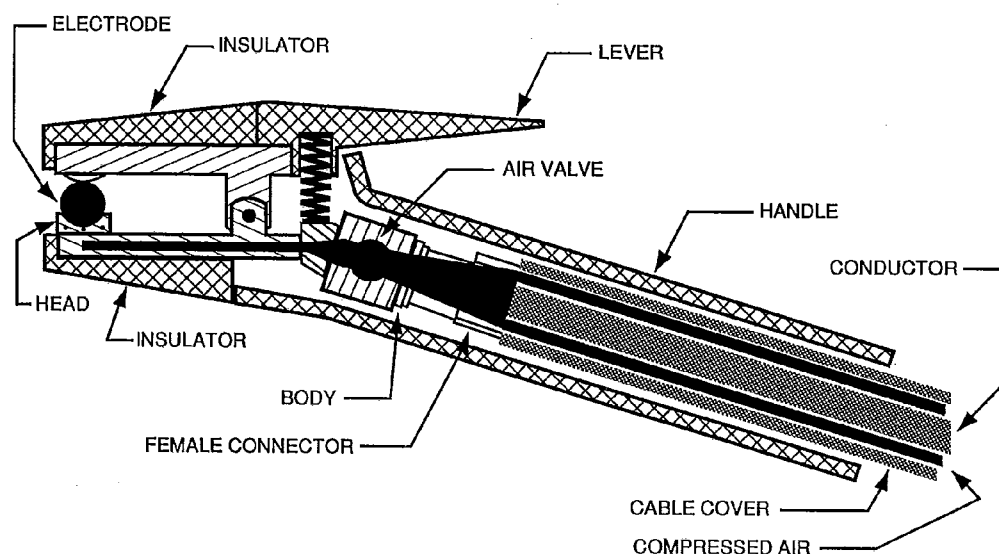


Figure 3 — Manual Torch

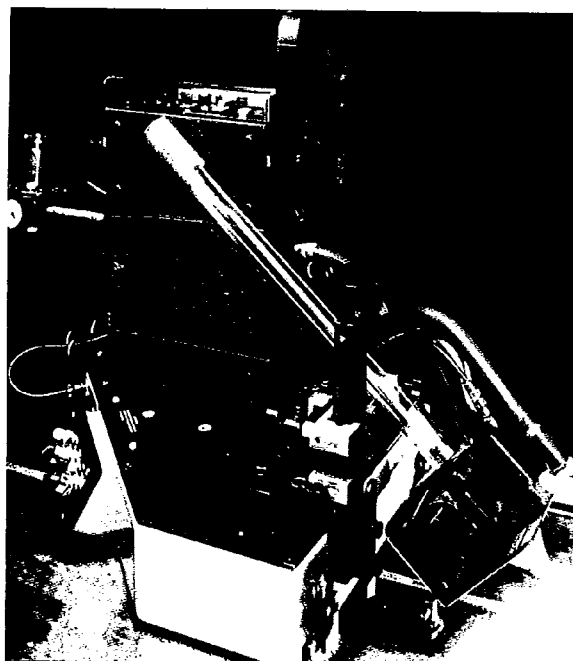


Figure 4 — Mechanized Cutting Torch

2.7.3 A dual system is capable of operation by an internal selector switch in either of the modes described above.

3. Operating Techniques

3.1 Gouging. The electrode is gripped, as shown in Figure 5, so that a maximum of 7 inches extends from the cutting torch. For nonferrous materials, this extension should be reduced to 3 inches. Table 3 shows suggested current ranges for various electrode types and sizes.

The air jet should be turned on before striking the arc, and the cutting torch should be held as shown in Figure 6. The electrode slopes back from the direction of travel with the air jet behind the electrode. Under proper operating conditions, the air jet is expected to sweep beneath the electrode end and remove all molten metal. The arc may be struck by lightly touching the electrode to the workpiece. The electrode should not be drawn back once the arc is struck. The gouging technique is different from that of arc welding because metal is removed instead of deposited. A short arc should be maintained by progressing in the direction of the cut fast enough to keep up with metal removal. The steadiness of progression controls the smoothness of the resulting cut surface.

For gouging in the vertical position, the cutting torch should be held as shown in Figure 7. Gouging should be done in a downhill direction, which permits gravity to assist in removing the molten metal. Vertical gouging may be done in the opposite direction, but it is more difficult. Gouging in the horizontal position may be done either to the right or to the left, but always with forehand gouging.

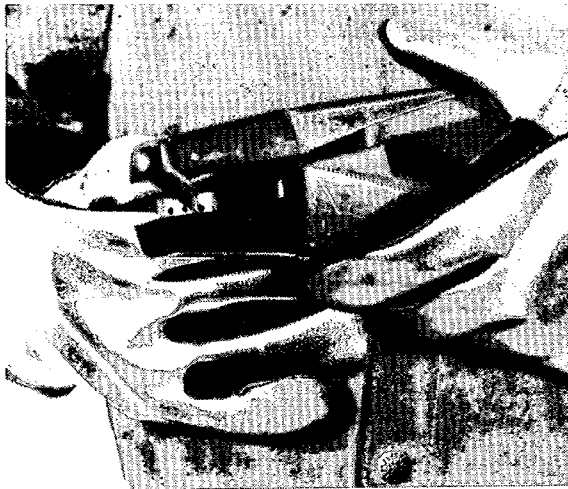


Figure 5 — Electrode Position

Table 3
Suggested Current Ranges for
Commonly Used Electrode Types and Sizes

Electrode Diameter (inches)	DC, DCEP Polarity		AC Electrode	
	Minimum (amperes)	Maximum (amperes)	Minimum (amperes)	Maximum (amperes)
1/8	30	60		
5/32	90	150		
3/16	200	250	200	250
1/4	300	400	300	400
5/16	350	450	325	425
3/8	450	600	350	450
1/2	800	1000	500	600
5/8	1000	1250		
3/4	1250	1600		
1	1600	2200		
3/8 Flat	250	450		
5/8 Flat	300	500		

In gouging to the left, the cutting torch should be held as shown in Figure 8. In gouging to the right, the cutting torch will be reversed to locate the air jet behind the electrode.

When gouging in the overhead position, the electrode and torch should be held at an angle that will prevent molten metal from dripping on the cutter's glove, as shown in Figure 9.

The depth of the groove produced is controlled by the travel speed. Grooves up to 1 inch deep may be made. However, the deeper the groove, the more experienced cutter is required. Slow travel speeds produce a deep

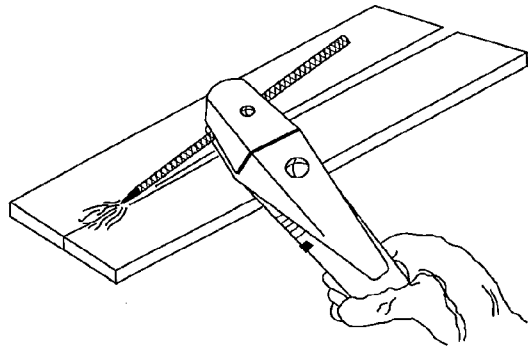


Figure 6 — Flat Position Gouging

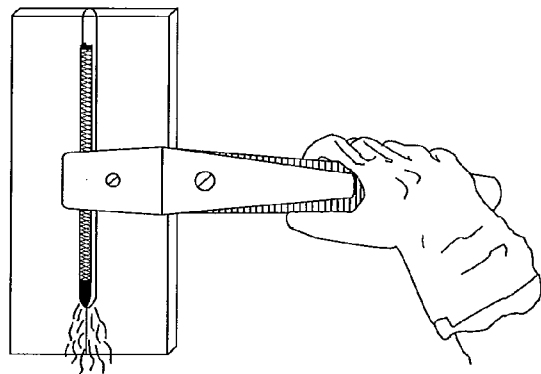


Figure 7 — Vertical Position Gouging

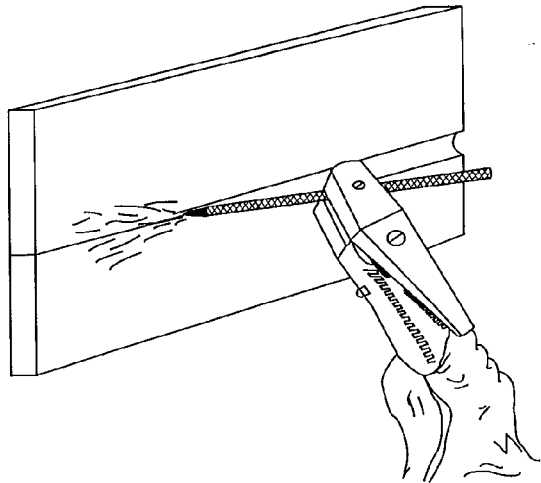


Figure 8 — Horizontal Position Gouging

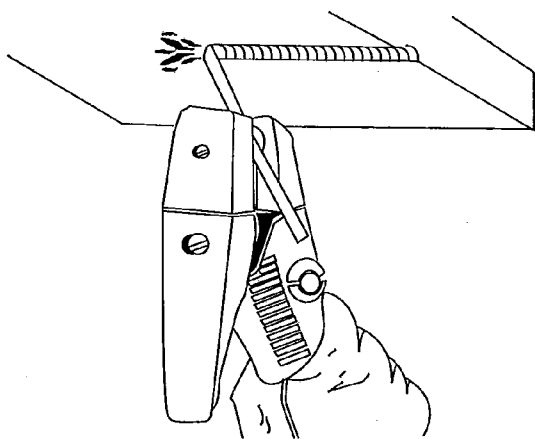


Figure 9 — Overhead Position Gouging

groove. Fast speeds will produce shallow grooves. The width of the groove is determined by the size of the electrode used and is usually about 1/8 inch wider than the electrode diameter. Wider grooves may be made with an electrode that is oscillated with a circular or weave

motion. When gouging, a push angle of 35 degrees from the surface of the workpiece is used for most applications. A steady rest is recommended in gouging to ensure a smoothly gouged surface. It is particularly advantageous for use in the overhead position. Proper travel speed depends on the size of the electrode, base metal, cutting amperage, and air pressure. Proper speed, which produces a smooth hissing sound, will result in a smooth gouge.

3.2 Severing. Figure 10 shows the electrode in position for severing. In general, the severing technique is the same as for gouging, except that the electrode is held at a steeper angle; that is, with a push angle between 70 and 80 degrees.

For cutting thick nonferrous metals, the electrode should be held perpendicular to the workpiece surface, with the air jet in front of the electrode in the direction of travel. With the electrode in this position, the metal may then be severed by moving the arc up and down through the metal with a sawing motion.

3.3 Washing. In using the air carbon arc cutting process for removing metal from large areas, such as the removal of surfacing metal and of riser pads on castings, the proper position of the electrode is shown in Figure 11.

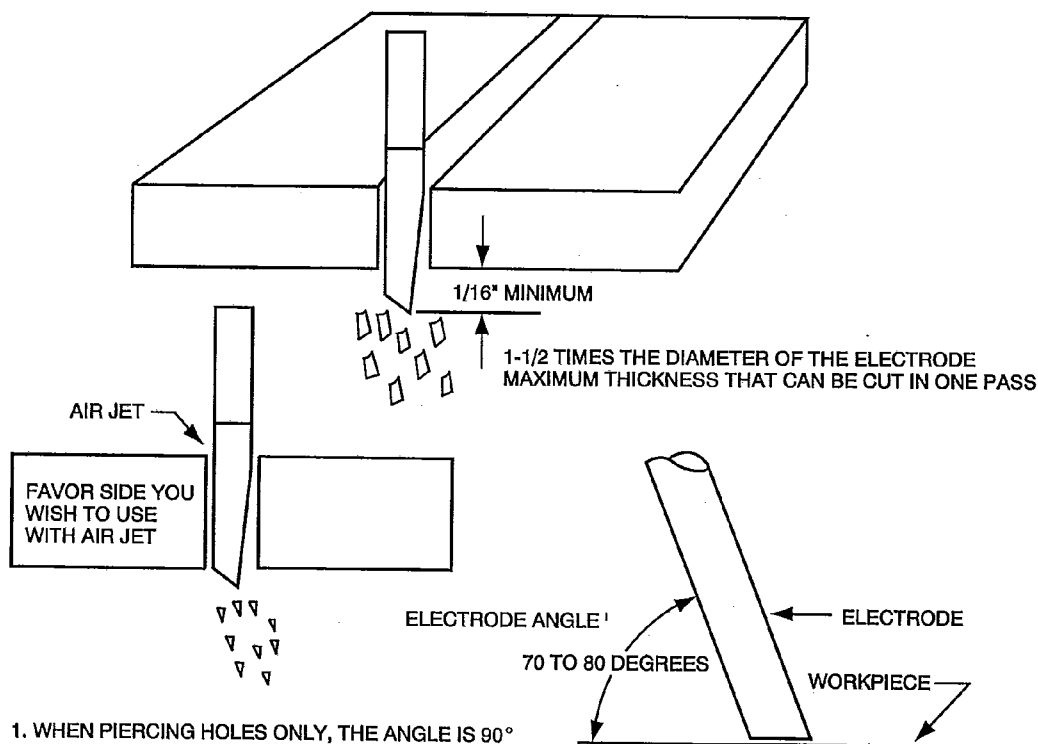
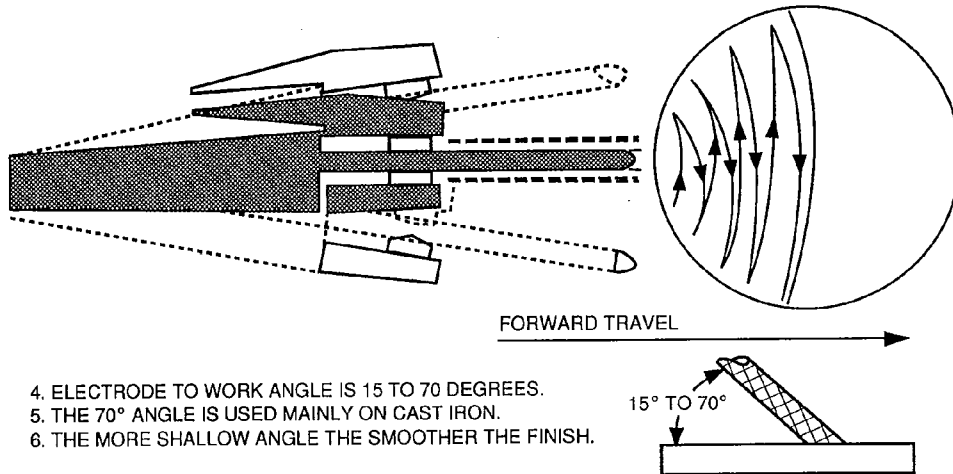


Figure 10 — Severing/Piercing with CAC-A

PADWASHING TECHNIQUE

1. TORCH REMAINS PARALLEL TO THE WORKPIECE.
2. A WEAVING MOTION SIDE TO SIDE THE WIDTH OF THE AREA BEING CLEANED.
3. MAINTAIN MOTION FORWARD ACROSS THE WORKPIECE.



4. ELECTRODE TO WORK ANGLE IS 15 TO 70 DEGREES.
5. THE 70° ANGLE IS USED MAINLY ON CAST IRON.
6. THE MORE SHALLOW ANGLE THE SMOOTHER THE FINISH.

Figure 11 — Pad Washing with CAC-A

The electrode should be oscillated from side to side while pushing forward at the depth desired. In pad washing operations, a push angle of 15 to 70 degrees to the workpiece surface is used. The 15 degree angle is used for light finishing passes, while the steeper angles allow deeper rough cutting to be done with greater ease.

Particularly suited for this application are cutting torches with fixed angle heads that hold the electrode at the correct angle. With other types of torches, care should be taken to keep the air jet behind the electrode. The steadiness of the cutter determines the smoothness of the surface produced.

3.4 Beveling. One beveling method is to hold the electrode, as in Figure 12(a), with a travel angle of 90 degrees, and a work angle equal to the bevel angle. The air jet is between the electrode and work piece. The second method is to hold the electrode as in Figure 12(b) with the torch parallel to the edge being beveled and the electrode angle equal to the bevel angle. The air jet is between the electrode and the workpiece surface.

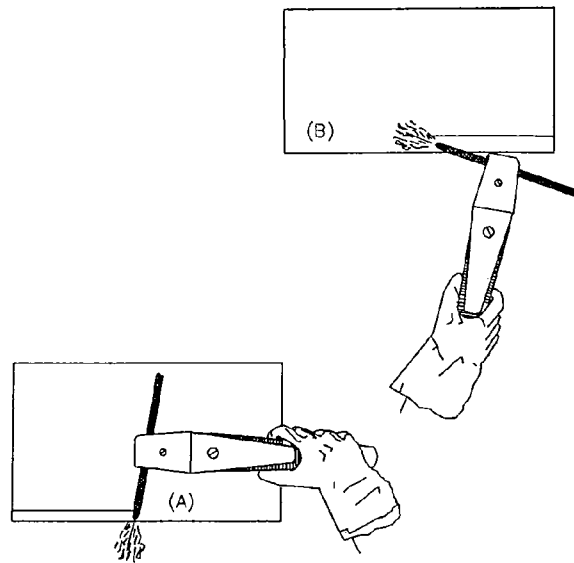


Figure 12 — Methods of Beveling with CAC-A

4. Equipment Selection

4.1 Cutting Torch. Determined by the job being done, torches range from light duty farm and body shop sizes to extra heavy duty foundry torches. The following is a guide for torch usage:

Cutting Torch Type	Application/Selection
Light Duty	Small shops, farms, maintenance and with limited air supply. Limited to a maximum of 450 amperes DC.

<u>Cutting Torch Type</u>	<u>Application/Selection</u>
General Purpose	Normal general purpose applications in shipyards, fabrication shops, and general maintenance. Limited to a maximum of 1000 amperes.
Heavy Duty Multipurpose	General foundry work, padwashing, and severing. High amperage work in shipyards and fabrication shops. Limited to 1600 amperes with air cooled cables and 2000 amperes with water cooled cables.
Mechanized	Edge preparations; high quality and high productivity applications. Used with 5/16 through 3/4 inch diameter jointed carbons.

4.2 Power Sources. Any three phase welding power source of sufficient capacity may be used for the air carbon arc gouging process, providing the manufacturer recommends its use for CAC-A. However, be sure the open-circuit voltage is high enough to allow for voltage drop in the circuit. The arc voltage used in air carbon arc gouging and cutting ranges from 28 to 56 volts (V); thus the open-circuit voltage should be at least 60 V. Some constant potential power sources require very high OCV to operate air carbon arc cutting equipment. Single phase power sources are generally inadequate for this process. Power sources being used in conjunction with mechanized cutting and other applications requiring maximum arc time should be rated 100% duty cycle for the required amperage.

<u>Current</u>	<u>Type</u>	<u>Remarks</u>
DC	constant current motor generator, rectifier, or resistor grid unit).	Preferred power supply for all electrode sizes.
	constant potential (motor generator or rectifier)	Usable only for 5/16 inch and larger diameter electrodes. May cause carbon deposits with smaller electrodes. Not suitable for mechanized torches with voltage control only.
AC	AC constant current (transformer)	Recommended for AC electrodes only.
AC/DC	transformer rectifiers	DC supplied from three phase transformer-rectifier sources is satisfactory, but DC from single phase

<u>Current</u>	<u>Type</u>	<u>Remarks</u>
		supplies gives unsatisfactory arc characteristics. AC output from AC/DC is satisfactory, provided AC electrodes are used.

4.3 Mechanized Systems. Mechanized systems are used more in the fabrication industry. These systems offer a high quality, high productivity alternative to manual cutting. There are two types of systems to be considered, both operating on a signal from the arc to control the gouging.

4.3.1 Dual Signal System. With this type of mechanized system, either constant current or constant potential power supplies can be used. When utilizing constant current, the arc length is maintained through a voltage signal system. A predetermined voltage setting is set on the system controller, which then advances or retracts the electrode through a stepping motor to maintain the arc length. On a constant potential power supply, amperage sensing controls the feeding or retracting of the electrode to maintain the desired arc current.

4.3.2 Single Signal System (Voltage Control Only). This type system also maintains arc length through a voltage signal as above, but will not operate with an amperage signal. This type of system operates only on a CC power supply.

4.3.3 Advantages. Mechanized CAC-A systems offer substantial improvements in both productivity and quality. They are capable of out-of-position gouging and are particularly adaptable to producing long gouges in flat workpieces with a moving gouging apparatus, and for circular gouges in pipe and tanks with the gouging apparatus remaining stationary. They produce a very consistent U-groove configuration and can control depth of the groove to within 0.025 inch. Tables 4 and 5 give typical operating conditions for both U- and J-grooves.

5. Process Variables

5.1 Process Variables. The air carbon arc cutting process is sensitive to improper operation, as is any thermal cutting process. Variables can cause changes in the finished gouge that range from undetectable to unacceptable results. Primary variables that require attention are listed, with more detailed information.

<u>Variable</u>	<u>Function</u>
Electrode Diameter	Determines the size of the groove.

Table 4
Mechanized CAC-A
U-Groove Gouging Conditions

Electrode Diameter (inches)	Desired Depth (inches)	Travel Speed (inches/minute)	DCEP Polarity (amperes)
5/16	1/8	65	400
	3/16	45	
	1/4	36	
	5/16	33	
	7/16	22	
3/8	1/8	70	500
	3/16	44	
	1/4	35	
	3/8	20	
	9/16	17	
1/2	1/8	96	850
	1/4	57	
	3/8	35	
	1/2	24	
	3/4	18	
5/8	1/4	72	1250
	3/8	48	
	1/2	37	
	5/8	30	
	7/8	20	
3/4	3/8	42	1400
	1/2	34	
	5/8	27	
	3/4	22	
	1	18	

Note: If the groove depth is 1-1/2 times the electrode diameter being used, make two or more passes.

Variable**Function**

Amperage	Determined by the diameter of electrode being used. It is the current flow performing the melting of the base metal.
Voltage	The pressure behind the amperage, or the arc force. Determined by arc length on CC power supplies and set on CV power supplies.
Air Pressure & Flow Rate	The medium for removal of the molten metal.
Travel Speed	Determines the depth/quality of a finished groove.
Electrode Travel and Work Angle	Can determine groove shape.
Electrode Extension	Affects metal removal rates and quality of groove.
Base Metal	Determines selection of parameters for other variables.

5.2 Electrode Diameter and Type. This is the most dominant factor in determining the size of the groove. The proper choice of electrode can affect productivity, groove quality and metal removal rates. The width of the groove will be approximately 1/8 inch wider than the diameter of the electrode. In choosing the proper electrode, the size of the desired groove should be the deciding factor, with available power dictating the maximum electrode diameter. As an example, a 1/2 inch wide, 1/4 inch deep groove 10 inches long could be made manually in two passes using a 1/4 inch electrode, or in one pass with a 3/8 inch diameter electrode. In the

Table 5
Mechanized CAC-A J-Groove Gouging Conditions

Base Metal Thick.	Electrode Data			Electrode Overhang (inches)			Travel Speed (inches/minute)					Compressed Air		
				Pass 1	Pass 2	Pass 3	Power Data		Pass 1	Pass 2	Pass 3			Avg. Speed
Dia.	Angle	Slick Out	Amps	Volts										
3/8	5/16	45	4	.063			450	42	65			65	30	60
1/2	5/16	45	4	.063			450	42	35			35	30	60
5/8	3/8	45	4	.063	.063		600	42	50	50		25	30	60
3/4	3/8	45	4	.063	.063		600	42	37	37		22	30	60
1	5/8	45	4	.125	.125		1250	42	40	40		20	30	60
1-1/2	5/8	45	4	.063	.063	.063	1250	42	47	47	47	16	30	60
2	5/8	45	4	.125	.125	.125	1250	42	28	28	28	10	30	60

former, the effective travel gouging rate would be 10 inches per minute per pass. Therefore the effective travel speed is 5 inches per minute (10 IPM divided by 2 passes). The travel speed or gouging rate for 3/8" is 17 inches per minute. This is more than a 200% increase in gouging rate and will offset the additional electrode cost. Mechanized systems even further increase the productivity rate due to the finite control of the arc voltage.

5.3 Amperage. The gouging amperage determines the melting rate of the process. It is determined by the electrode size. Set too low for the electrode size, the melting rate of the base metal will be inadequate, and free carbon deposits will occur. A setting too high, while melting the base metal, will cause rapid deterioration of the electrode with subsequent reduction in metal removed per electrode. This condition can also substantially reduce torch life.

5.4 Voltage. Voltage is determined by the arc length and the current flow through the arc. CAC-A generally requires a higher voltage than most welding processes. This requirement limits proper operation to power supplies with high enough open circuit voltage to maintain a 28 volt operating minimum. Inadequate voltage can create a sputtering arc or actually prevent arc establishment. This results in uneven grooves with a high probability of free carbon deposits, requiring excessive grinding to remove.

5.5 Air Pressure and Flow Rate. The air jet is the medium for the removal of the molten metal. Both adequate pressure and flow rate are required to obtain the proper results. This variable is probably one of the most abused of all the variables discussed. The flow rate in cubic feet per minute (cfm) is as important as the air pressure. The pressure is the variable that determines the velocity of the air that moves the molten metal out of the groove area. If there is not enough flow to lift the molten metal out of the groove, the air jet cannot remove the molten metal, resulting in excessive slag adhesion and unnecessary grinding to clean the groove.

5.6 Travel Speed. Travel speed is the variable that directly affects the depth of the gouge as well as the resulting quality of the groove. The faster the travel for any given diameter electrode, the shallower the gouge. If the travel speed is too fast for the cutter's comfort, a smaller electrode size should be used, or a move to mechanized gouging should be considered. Attempting a groove too deep for the electrode diameter creates a poor quality groove that requires excessive grinding.

5.7 Electrode Push Angle. The electrode push angle is the most forgiving of the process variables. When gouging manually, a greater angle tends to give a more V shaped groove. With the mechanized system a greater

angle will give a slightly deeper groove, with the same travel speed, as a groove made with a lesser angle.

5.8 Base Metals

5.8.1 Gouging Recommendations

Base Metal	Recommendations
Carbon steel and low alloy steel, such as ASTM A514 and A517	Use DC electrodes with DCEP (electrode positive). AC electrodes with an AC transformer can be used, but for this application, AC is only 50% as efficient as DC.
Stainless steel	Same as for carbon steel.
Cast iron, including malleable and ductile iron	Use of 1/2" or larger electrodes at the highest rated amperage is necessary. There are also special techniques that need to be used when gouging these metals. The push angle should be at least 70 degrees and depth of the cut should not exceed 1/2 inch per pass.
Copper alloys (copper content 60% and under)	Use DC electrodes with DCEN (electrode negative) at maximum amperage rating of the electrode.
Copper alloys (copper content over 60%, or size of workpiece is large)	Use DC electrodes with DCEN at maximum amperage rating of the electrode or use AC electrodes with AC.
Aluminum bronze and aluminum nickel bronze (special naval propeller alloy)	Use DC electrodes with DCEN.
Nickel alloys (nickel content is over 80%)	Use AC electrodes with AC.
Nickel alloys (nickel content less than 80%)	Use DC electrodes with DCEP.
Magnesium alloys	Use DC electrodes with DCEP. Before welding, surface of groove should be wire brushed.
Aluminum	Use DC electrodes with DCEP. Wire brushing with stainless wire brushes is mandatory prior to welding. Electrode extension (length of

Base Metal**Recommendations**

	electrode between electrode torch and workpiece) should not exceed 3 inches for good quality work. DC electrodes with DCEN can also be used.
Titanium, zirconium, hafnium, and their alloys	Should not be cut or gouged in preparation for welding or remelting without subsequent mechanical removal of surface layer from cut surface.

Note: Where preheat is required for welding, similar preheat should be used for gouging.

5.8.2 Effects of the Cutting Process on Base Metals.

To avoid difficulties with carburized metal, users of the air carbon arc cutting process should be aware of the metallurgical events that occur during gouging and cutting. With DCEP, and the corresponding half cycle of alternating current, the current flow carries ionized carbon atoms from the electrode to the base metal. The free carbon particles are rapidly absorbed by the melted base metal. Increased carbon can lead to increased hardness and possible cracking. Since this absorption cannot be avoided, it is important that all carburized molten metal be removed from the cut surface, preferably by the air jet.

When the air carbon arc cutting process is used under improper conditions, the carburized molten metal left on the surface may usually be recognized by its dull gray-black color. This is in contrast to the bright blue color of the properly made groove. Inadequate air flow may leave small pools of carburized metal in the bottom of the groove. Irregular electrode travel, which is particularly true for manual gouging, may produce ripples in the groove wall that tend to trap the carburized metal. Finally, an improper electrode push angle may cause small beads of carburized metal to remain along the edge of the groove.

The effect of carburized metal on the cut surface during subsequent welding depends on many factors, including the amount of carburized metal present, the welding process to be employed, the kind of base metal, and the weld quality required. Although it may seem that filler metal deposited on the surface during welding should assimilate small pools or beads of carburized metal, experience with steel base metals shows that traces of metal containing approximately 1% carbon may remain along the weld interface. These imperfections become more significant with demands for increasing weld strength and toughness.

There is no evidence that the copper from copper-coated electrodes is transferred to the cut surface in base metal, except when the process is improperly used.

Carburized metal on the cut surface may be removed by grinding, but it is much more efficient to conduct air carbon arc gouging and cutting properly within prescribed conditions to completely avoid the retention of undesirable metal.

Studies have been conducted on stainless steel to determine whether air carbon arc gouging, carried out in the prescribed manner, would adversely affect corrosion resistance. Results of the studies are shown in Table 6. Type 304L stainless steel was welded using several processes. Backgouging of the joint was performed by air carbon arc gouging and by grinding. Specimens from the joints were subjected to the boiling 65% nitric acid test.

Corrosion rates typical for Type 304L stainless steel were obtained, and the results showed no significant difference in the corrosion rates of welds prepared by CAC-A and those prepared by grinding. Had any appreciable carbon absorption occurred, the corrosion rates for welds backgouged by CAC-A would have been significantly higher.

Compared to oxyfuel gas cutting, CAC-A is a lower energy input process. Therefore, a workpiece gouged or cut by CAC-A is less distorted. The machinability of low carbon and nonhardenable steels is not affected by the air carbon arc cutting process. With cast iron and high carbon steels, however, this process may cause sufficient hardening to make the cut surface nonmachinable. Nevertheless, because the hardened zone is shallow (approximately, 0.06 inch), a cutting tool is able to penetrate the hardened zone and remove this layer.

6. Advantages and Limitations**6.1 Advantages**

6.1.1 Fast. Five times faster than chipping. Gouges a groove 3/8 inch deep at over 2 feet per minute.

Table 6
Results of Corrosion Testing
on Type 304L Stainless Steel

Welding Process	Welding Position	Root Preparation Method	Corrosion Rate Per Month (inches)
GMAW	Horizontal	Gouge	0.000593
GTAW	Horizontal	Gouge	0.000594
GMAW	Horizontal	Grind	0.000646
GTAW	Horizontal	Grind	0.000618
GMAW	Vertical	Gouge	0.000686
SMAW	Vertical	Gouge	0.000627
SMAW	Vertical	Grind	0.000667
SMAW	Overhead	Grind	0.000632
SMAW	Overhead	Gouge	0.000645

6.1.2 Easily Controllable. Removes defects with precision. Defects are clearly visible in the groove and may be followed with ease. The depth of the cut is easily regulated, and slag does not deflect or hamper the cutting action.

6.1.3 Low Equipment Cost. No gas cylinders or regulators are necessary except in field operations.

6.1.4 Economical to Operate. No oxygen or fuel gas required. The welder or welding operator may also do the gouging or cutting.

6.1.5 Easy to Operate. Welders operate the equipment after a few minutes of instruction and become proficient in a few days. The torch contains an air-control valve and rotating nozzle that permits changing the electrode position to suit the job while maintaining alignment of the air jet.

6.1.6 Compact. The torch is not much larger than a shielded metal arc electrode holder.

6.1.7 Versatile. Used anywhere it is possible to weld. May be operated in spaces too restricted to accommodate a chipping hammer or an oxyfuel gas cutting torch. Requires no difficult adjustments for use on different metals.

6.1.8 Cuts Cleanly. Resulting surface is clean and smooth. Welding or brazing may generally be done without grinding or cleaning.

6.2 Limitations

6.2.1 Other cutting processes are better for severing.

6.2.2 Requires large volume of compressed air.

6.2.3 Increases surface hardness on cast iron and air hardenable metals. This may be objectionable.

6.2.4 Depth of cut is limited to electrode depth of fusion.

6.2.5 Accompanied by noise, fumes, and discharge of sparks and molten metal.

7. Areas of Application

Some areas in which the air carbon arc cutting process has been utilized are as follows:

Agriculture. Preparing joints of broken metals on farm machinery for welding. Removal of surfacing welds. Severing metals.

Aircraft. Maintenance of ground equipment and airport structures. Repairing dies and fixtures.

Automotive. Maintenance. Preparation of broken cast iron parts. Severing metals. Removing broken or seized bearing races, collars, etc., from shafts.

Boiler Shops. Removing rivets and defective welds. Preparing cracks for rewelding. Removing tubes from tube sheets.

Breweries. Maintenance of equipment, vats, piping, etc. Cutting and gouging all types of metals, especially stainless steels.

Chemical Plants. Preparing equipment and piping of stainless steel and nonferrous metals for repair and alteration by welding.

Construction. Preparation of joint for welding. Removal of defects in welds. Fabrication without beveling. Removing holding clips, lifting pads, etc., without damage to pads or structure. Maintenance of equipment.

Contractors. Maintenance of equipment. Removal of surfacing welds, shovel teeth, and stainless steel welds. Preparing cast iron and manganese steel for welding, including repointing of dipper teeth. Preparing cast iron for repair by welding.

Dredging. Maintenance of equipment. Preparation of manganese steel parts for repair by welding. Removal of surfacing welds.

Foundries. Padwashing, removing fins and risers. Removing cracks, sand pockets, and other defects from casting. Maintenance of equipment.

Surfacing Shops. Removal of old surfacing welds. Preparing stainless and manganese steels for welding. Removing defective welds.

Lumber Industry. Maintenance of equipment. Removing surfacing welds. Dismantling of damaged equipment for repair and reuse. Preparing cast iron for welding or braze welding.

Maintenance Shops. Dismantling and remodeling equipment. Removing surfacing welds. Severing metals. Preparation of damaged areas for repair welding.

Army/Marines. Removal of austenitic steel weld metal. Back gouging welds for welding the second side. Salvaging armor plates. Severing metals. Removal of defects in welds and castings.

Navy/Coast Guard. Removal of defects in welds and castings. Back gouging to weld the second side. Removal of austenitic steel weld metals. Removing padeyes, dogs, etc., without damage to attachments or to existing structures. Grooving of thin plate for welding. Removing eroded areas in ship's hulls, stern tubes, struts, skegs, rudders, and propellers for repair by welding. Removal

of bulkheads, patches, and access hatches for reuse by damage control.

Mining. Maintenance of equipment. Cutting manganese steels, cast iron, and all nonferrous metals. Remove surfacing welds.

Oil Refineries. Removing defective welds. Cutting and gouging stainless and austenitic welds. Cutting out or patching tank bottoms and coke and pipe stills. Removing liners, boiler and heat exchanger tubes, and rivets. Removing defects and preparing breaks in castings for repair by welding. Cutting nonferrous metals. Removing risers on castings. Preparing the surface of eroded and corroded areas on acid plant equipment for rebuilding by welding.

Oil Drilling. Grooving for welding of plates. Removing drill collars. Remove surfacing welds. Gouging out defects and grooving edges of castings (mud pumps), etc. for welding. Maintenance of equipment. Removal of fish plates on truck chassis for renewal. Grooving of broken edges for rewelding.

Packing Houses. Preparing equipment, vats, and piping of stainless steel and nonferrous metal for welding.

Power Plants. Maintenance of equipment. Grooving of metal for welding. Gouging out castings for repair. Removal of cavities from hydroturbine wheels. Removal of welded end tubes from tube sheets. Removal of welding defects. Cutting and preparing cast iron for welding or braze welding.

Railroads. Maintenance of equipment. Removal of journal liners, rivets, welded end tubes from tube sheets. Preparation of breaks in boilers, fire boxes, etc., for repair by welding. As salvage and rescue tool after wreckage of equipment. Preparation for weld surfacing or its removal from frogs, switches, and rail ends. Preparing manganese steel for welding. Removal of riser pads and defects from castings in foundries. Preparing worn wheels for rebuilding by welding.

Salvage Yards. Cutting all scrap. Removing welds without damaging structure for reuse. Cutting all types of stainless steel, nonferrous metals, and cast iron.

Shipbuilding. See Navy/Coast Guard.

Stainless Shops. Cutting stainless steel. Removing defects in stainless steel castings and welds.

Steel Fabricators. Welding and fitting plates without beveling by backgouging the second side to sound metal after welding the first side. Removal of welds from existing structures and salvaging undamaged material for reuse. Cutting and gouging all metals in the shop and at the job site. Maintenance of equipment.

Steel Mills. Maintenance of equipment. Cutting and gouging all metals. Washing billets, blooms. Removal of defects.

Waterworks. Preparation of broken equipment for repair by welding. Cutting and gouging all metals. Cutting cast iron pipe, especially concrete lined. Removal of defective pipe sections for installation of new sections by removing welds.

Welding Shops. Removing welds. Cutting all metals, especially nonferrous metals, stainless steel, and cast iron. Cutting bevels and back gouging weld roots. Removal of surfacing welds.

8. Trouble Shooting

Problems associated with air carbon arc cutting process and suggested solutions are:

<u>Problem</u>	<u>Solution</u>
Large free carbon deposit at the beginning of the groove.	The cutter either neglected to turn on the air jet before striking the arc, or the torch was located improperly. The air should be turned on before striking the arc and should flow between the electrode and the workpiece behind the electrode in the direction of travel.
An unsteady arc, causing the cutter to use a slow travel speed even on shallow grooves.	The amperage was insufficient for the electrode diameter used (see Table 3). While the minimum recommended amperage may be sufficient, it does require a higher degree of cutter skill. The middle of the range is much more efficient. If the desired amperage cannot be obtained from the available power source, greater efficiency would be obtained by using a smaller diameter electrode.
Erratic groove with the arc wandering from side to side and with the electrode heating rapidly.	The process was apparently used with DCEN (electrode negative). Direct current electrodes should be used with DCEP on all metals, with the exception of a few copper alloys.
Intermittent arc action resulting in an irregular groove surface.	The travel speed was too slow in manual gouging. Generally the cutter has fixed his position by setting his hand on the work-

<u>Problem</u>	<u>Solution</u>	<u>Problem</u>	<u>Solution</u>
	piece. Since the speed of air carbon arc gouging is much faster than shielded metal-arc welding, friction between the gloved hand and the workpiece may cause an erratic forward motion. This causes the arc length between the electrode and workpiece to become too large to maintain the arc. The cutting operator should assume a comfortable position so that his arms can move freely and his gloves do not drag on the work. If mechanized equipment is involved, check Table 4 for proper operating conditions.		ing the concentric cable assembly should have a minimum ID of 3/8 inch for manual torches. For mechanized torches that do not require a concentric cable, the minimum hose ID should be 1/2 inch.
In gouging, carbon deposits at varying groove intervals; in padwashing, carbon deposits at various spots on the washed surface.	The electrode has shorted out on the workpiece. In manual gouging, this condition is caused by using travel speed excessive for the amperage used and for the depth of the groove being made. In mechanized operations, it is caused either by excessive travel speed or by using a flat-curve constant potential power source for a small diameter electrode of 5/16 inch. In pad washing, this shorting out is caused by holding the electrode at too small a push angle. An electrode push angle of 15 to 70 degrees from the workpiece surface is recommended. A smaller angle increases the arcing area, which reduces the current density; this reduction in arc current density requires a decrease in arc length, to the point of short circuiting. Care must be taken to maintain the proper arc gap.	9. Safe Practices 9.1 Introduction. The general subject of safety and safe practices in welding and thermal cutting processes, such as air carbon arc, is covered in ANSI Z49.1, "Safety in Welding and Cutting", and ANSI Z49.2, "Fire Prevention in Use of Welding and Cutting Processes." Air carbon arc cutters and their supervisors should be familiar with the practices discussed in these documents. In addition, there are other potential hazard areas in arc welding and cutting (besides fume, gases and radiant energy), such as noise and improper use of pressure regulators, which warrant consideration. Those areas associated with air carbon arc cutting are briefly discussed in this section. 9.2 Noise. Excessive noise is a known health hazard. Exposure to excessive noise can cause a loss of hearing. The loss of hearing can be either full or partial, and temporary or permanent. In welding, cutting and allied operations, noise may result from the process, the power source, or other equipment. Air carbon arc and plasma arc are examples of processes which are frequently noisy. Engines of engine-driven generators may also be quite noisy. Excessive noise adversely affects hearing capability. This adverse effect in hearing capability may be a temporary threshold shift from which ears may recover if removed from the noise source. However, if a person is exposed to the same noise level for a longer time, then the loss of hearing may become permanent. The time required to develop permanent hearing loss depends upon factors such as individual susceptibility, noise level, and exposure time. In addition, there is evidence that excessive noise affects other bodily functions and behavior. A direct method to protect against excessive noise is to reduce the intensity of the source. Another method is to shield the source, but this has limitations. The acoustical characteristics of a room will also affect the level of noise. When engineering control methods fail to reduce the noise, personal protective devices such as ear muffs or ear plugs may be employed. Generally, these devices are only accepted when engineering controls are not fully effective.	
Irregular groove, too deep, then too shallow.	The cutter was unsteady. The cutter should relax and assume a comfortable position when gouging.		
Slag adhering to the edges of the groove.	Slag ejection was inadequate. For adequate slag ejection, proper air pressure and flow rate (cfm) should be used. Air pressure, between 80 and 100 psi (550–690 kPa), may not effectively eject all of the slag if the volume is insufficient. To deliver adequate volume, the air hose feed-		

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The permissible noise exposure limits can be found in the CFR Title 29, Chapter XVII, Part 1910. This is available from the U.S. Government Printing Office, Washington, D.C. 20402. Additional information may be found in the *Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment*, published by the American Conference of Government Industrial Hygienists, 6500 Glenway Avenue, Bldg. D-5, Cincinnati, OH 45211.

A recommended method for measuring noise emitted by arc welding processes may be found in ANSI F6.1-78, *Method for Sound Level Measurement of Manual Arc Welding and Cutting Processes*, published by American Welding Society, P.O. Box 351040, Miami, FL 33135.

9.3 Gases. The major toxic gases associated with arc cutting are ozone, nitrogen dioxide and carbon monoxide. Phosgene gas could be present as a result of thermal or ultraviolet decomposition of chlorinated hydrocarbon cleaning agents or suspension agents used in some aerosol anti-spatter agents or paints. Degreasing or other operations involving chlorinated hydrocarbons should be so located that vapors from these operations cannot be reached by radiation from the arc.

9.3.1 Ozone. The ultraviolet light emitted from the arc acts on the oxygen in the surrounding atmosphere to produce ozone. The amounts of ozone produced will depend upon the intensity and the wave length of the ultraviolet energy, the humidity, the amount of screening afforded by the fume and other factors. The ozone concentration will generally be increased with an increase in current and when aluminum is gouged. The concentration can be controlled by natural ventilation, local exhaust ventilation or by respiratory protective equipment described in ANSI Z49.1.

9.3.2 Nitrogen Dioxide. Some tests have shown that high concentrations of nitrogen dioxide are found only close to the arc. Natural ventilation reduces these concentrations quickly to safe levels in the cutter's breathing zone so long as the cutter keeps his head out of the fume plume.

9.3.3 Metal Fumes. The fumes generated by the CAC-A process can be controlled by natural ventilation, local exhaust ventilation or by respiratory protective equipment described in ANSI Z49.1. The method of ventilation required to keep the level of particulate and gases in the cutter's breathing zone within acceptable concentrations is directly dependent upon a number of factors, among which are the metal being cut, the size of the work area and the degree of confinement or obstruction to normal air movement where the cutting is taking place. Each operation should be evaluated on an individual basis in order to determine what will be required. Acceptable levels of particulate matter associated with cutting and designated as time-weighted average thresh-

Table 7
Particulate Matter with Possible
Significant Fume Concentration in the
Arc Cutter's Breathing Zone

Base Metal	Particulate Matter
Aluminum and aluminum alloys	Al, Mg, Mn, Cr, Si
Magnesium alloys	Mg, Al, Zn
Copper and copper alloys	Cu, Be, Zn, Pb, Sn, Si
Nickel and nickel alloys	Ni, Cu, Cr, Fe
Titanium and titanium alloys	Ti, Al, V
Austenitic stainless steels	Cr, Ni, Fe, Mn
Carbon steels*	Fe, Cu, Mn

* Also Cd, Sn and Zn for plated base metals.

old limit values (TLVs) and ceiling values have been established by the American Conference of Governmental Industrial Hygienists and by the Occupational Safety and Health Administration. Compliance with these levels can be tested by a sampling of the atmosphere under the cutter's helmet or in the immediate vicinity of the cutter's breathing zone. Sampling should be in accordance with AWS F1.1, *Method for Sampling Airborne Particulates Generated by Welding and Allied Processes*.

9.4 Radiant Energy. Any person within the immediate vicinity of the cutting arc should have adequate protection from radiation produced by the cutting arc. The filter shade recommended for CAC-A is a shade twelve or greater. Leather or wool clothing that is dark in color is recommended to better withstand the vigors of radiation, better resist burning and to reduce ultraviolet burns to the neck and face beneath the helmet.

10. Bibliography

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Appendix A

(This Appendix is not a part of ANSI/AWS C5.3-91, Recommended Practices for Air Carbon Arc Gouging and Cutting, but is included for information purposes only.)

Commonly Used Metric Conversions (Inch-Millimeter Conversion)

1 in. = 25.4 mm exactly

To convert inches to millimeters, multiply
the Inch value by 25.4.

To convert millimeters to Inches divide the
millimeter value by 25.4.

Inch and Millimeter Decimal Equivalents of Fractions of an Inch

Inch		Millimeter	Inch		Millimeter
Fraction	Decimal		Fraction	Decimal	
1/64	0.015 625	0.396 875	33/64	0.515 625	13.096 875
1/32	0.031 250	0.793 750	17/32	0.531 250	13.493 750
3/64	0.046 875	1.190 625	35/64	0.546 875	13.890 625
1/16	0.062 500	1.587 500	9/16	0.562 500	14.287 500
5/64	0.078 125	1.984 375	37/64	0.578 125	14.684 375
3/32	0.093 750	2.381 250	19/32	0.593 750	15.081 250
7/64	0.109 375	2.778 125	39/64	0.609 375	15.478 125
1/8	0.125 000	3.175 000	5/8	0.625 000	15.875 000
9/64	0.140 625	3.571 875	41/64	0.640 625	16.271 875
5/32	0.156 250	3.968 750	21/32	0.656 250	16.668 750
11/64	0.171 875	4.365 625	43/64	0.671 875	17.065 625
3/16	0.187 500	4.762 500	11/16	0.687 500	17.462 500
13/64	0.203 125	5.159 375	45/64	0.703 125	17.859 375
7/32	0.218 750	5.556 250	23/32	0.718 750	18.256 250
15/64	0.234 375	5.953 125	47/64	0.734 375	18.653 125
1/4	0.250 000	6.350 000	3/4	0.750 000	19.050 000
17/64	0.265 625	6.746 875	49/64	0.765 625	19.446 875
9/32	0.281 250	7.143 750	25/32	0.781 250	19.843 750
19/64	0.296 875	7.540 625	51/64	0.796 875	20.240 625
5/16	0.312 500	7.937 500	13/16	0.812 500	20.637 500
21/64	0.328 125	8.334 375	53/64	0.828 125	21.034 375
11/32	0.343 750	8.731 250	27/32	0.843 750	21.431 250
23/64	0.359 375	9.128 125	55/64	0.859 375	21.828 125
3/8	0.375 000	9.525 000	7/8	0.875 000	22.225 000
25/64	0.390 625	9.921 875	57/64	0.890 625	22.621 875
13/32	0.406 250	10.318 750	29/32	0.906 250	23.018 750
27/64	0.421 875	10.715 625	59/64	0.921 875	23.415 625
7/16	0.437 500	11.112 500	15/16	0.937 500	23.812 500
29/64	0.453 125	11.509 375	61/64	0.953 125	24.209 375
15/32	0.468 750	11.906 250	31/32	0.968 750	24.606 250
31/64	0.484 375	12.303 125	63/64	0.984 375	25.003 125
1/2	0.500 000	12.700 000	1	1.000 000	25.400 000

Document List

The following is a complete list of the documents prepared by the AWS Committee on Arc Welding and Cutting

- AWS C5.1 Plasma Arc Welding, Recommended Practices for
- AWS C5.2 Plasma Arc Cutting, Recommended Practices for
- AWS C5.3 Air Carbon Arc Gouging and Cutting, Recommended Practices for
- AWS C5.4 Stud Welding, Recommended Practices for
- AWS C5.5 Gas Tungsten Arc Welding, Recommended Practices for
- AWS C5.6 Gas Metal Arc Welding, Recommended Practices for
- AWS C5.7 Electrode Gas Welding, Recommended Practices for