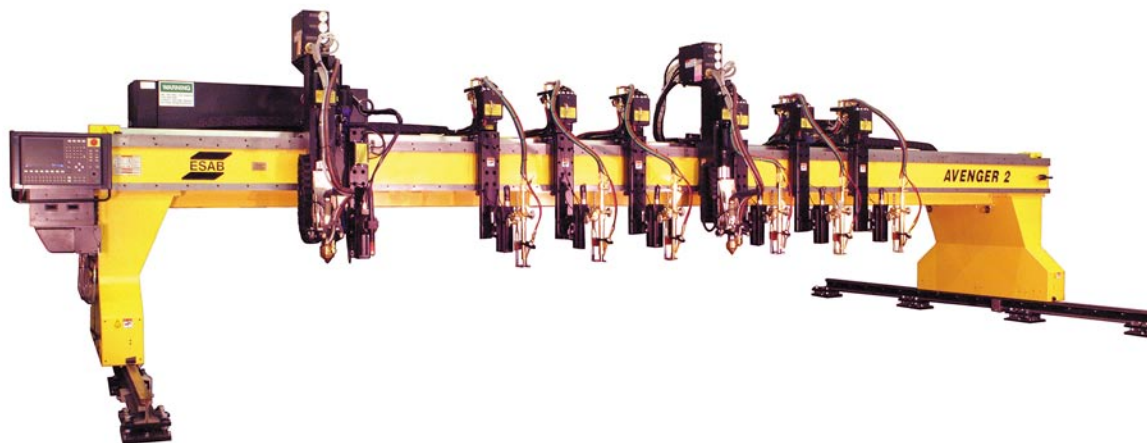
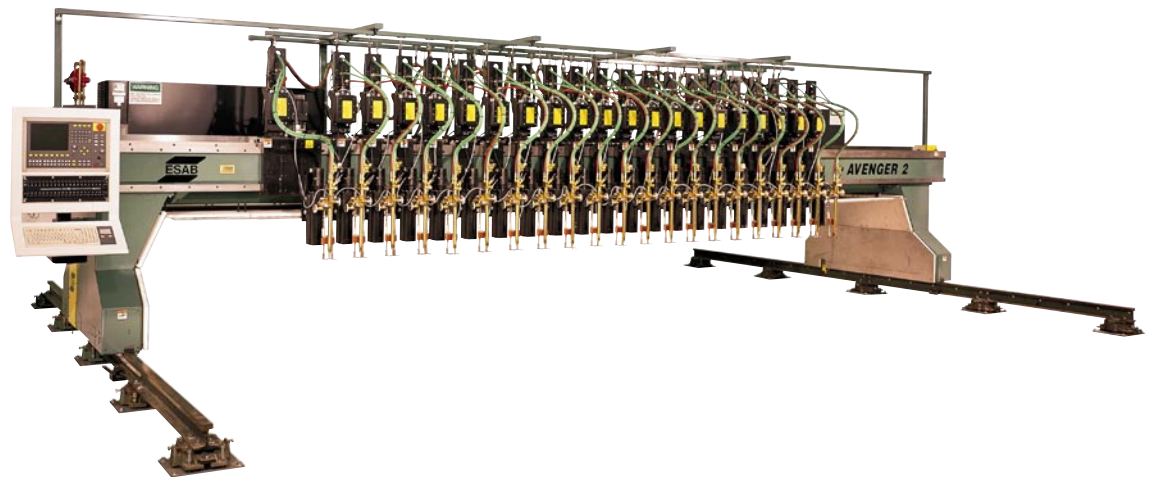




FACTORS AFFECTING QUALITY IN OXY-FUEL CUTTING



Operators Manual

**BE SURE THIS INFORMATION REACHES THE OPERATOR.
YOU CAN GET EXTRA COPIES THROUGH YOUR SUPPLIER.**

CAUTION

These INSTRUCTIONS are for experienced operators. If you are not fully familiar with the principles of operation and safe practices for arc welding and cutting equipment, we urge you to read our booklet, "Precautions and Safe Practices for Arc Welding, Cutting, and Gouging," Form 52-529. Do NOT permit untrained persons to install, operate, or maintain this equipment. Do NOT attempt to install or operate this equipment until you have read and fully understand these instructions. If you do not fully understand these instructions, contact your supplier for further information. Be sure to read the Safety Precautions before installing or operating this equipment.

USER RESPONSIBILITY

This equipment will perform in conformity with the description thereof contained in this manual and accompanying labels and/or inserts when installed, operated, maintained and repaired in accordance with the instructions provided. This equipment must be checked periodically. Malfunctioning or poorly maintained equipment should not be used. Parts that are broken, missing, worn, distorted or contaminated should be replaced immediately. Should such repair or replacement become necessary, the manufacturer recommends that a telephone or written request for service advice be made to the Authorized Distributor from whom it was purchased.

This equipment or any of its parts should not be altered without the prior written approval of the manufacturer. The user of this equipment shall have the sole responsibility for any malfunction which results from improper use, faulty maintenance, damage, improper repair or alteration by anyone other than the manufacturer or a service facility designated by the manufacturer.

TABLE OF CONTENTS

Introduction	5
Preheat	7
Oxygen Stream.....	11
Torch And Cutting Nozzles.....	15
Cutting Speed.....	21
Type Of Material Being Cut.....	25
Glossary of Terms.....	29
Procedures	31

TABLE OF CONTENTS

Introduction

Although oxy-fuel cutting is generally viewed as a mature uncomplicated process, those who work with it realize all too well that making it perform properly is no simple matter. Experienced operators can achieve a level of cut quality that rivals a machined surface, and do it in a fraction of the time cost of hard tooling. Consistently reaching that quality, however, requires an understanding of the many factors that are at work, their direct effect on quality, and their interaction with each other. For many operators, that can only be achieved through years of hands-on experience.

The information presented in this booklet is intended to reduce the learning time for less experienced operators by providing an understanding of the “how’s” and “why’s” of oxy-fuel cutting. However, even the most experienced operators will benefit by learning how some die-hard habits, viewed by some to improve cut quality and performance, can actually do more harm than good.

This booklet has divided the oxy-fuel cutting process into several key elements, their effect on quality and their interaction with each other. By understanding these fundamental relationships, all operators can reason the causes of various defects and then take corrective action to prevent them.

Basics Of Oxy-Fuel Cutting

Q. What is Oxy-Fuel Cutting?

A. Oxy-fuel cutting is a chemical reaction between pure oxygen and steel to form iron oxide. It can be described as rapid, controlled rusting.

Q. How does it work?

A. Preheat flames are used to raise the surface or edge of the steel to approximately 1800°F (bright red color). Pure oxygen is then directed toward the heated area in a fine, high pressure stream. As the steel is oxidized and blown away to form a cavity, the preheat and oxygen stream are moved at constant speed to form a continuous cut.

Q. Can I use oxy-fuel to cut any metal?

A. No. Only metals whose oxides have a lower melting point than the base metal itself can be cut with this process. Otherwise as soon as the metal oxidizes it terminates the oxidation by forming a protective crust. Only low carbon steel and some low alloys meet the above condition and can be cut effectively with the oxy-fuel process.

What Is Top Quality In Oxy-Fuel Cutting?

1. Square top corner (with minimum radius),
2. Cut face flat top to bottom (no undercut),
3. Cut face square with respect to top surface,
4. Clean smooth surface with near vertical drag lines, and
5. Little to no slag on bottom edge (easily removed by scraping)

Elements Of Oxy-Fuel Cutting

Preheat Flame

Oxygen Stream

Torch and Cutting Nozzle

Cutting Speed

Material Being Cut

Preheat Flame

The preheat flame is composed of fuel gas and oxygen at a proper mixture (ratio) to produce maximum flame temperature for greatest heating efficiency.

FLAME TEMPERATURES

Fuel Types	Base Of Brand Fuels	Oxy/Fuel Ratio	Maximum Temperature
Acetylene	None	1.5/1	5720°F
Methyl Acetylene type	MAPP	3.5/1	5340°F
Propylene	Chemolene, Mapolene, Hpg, FG-2	3.5/1	5240°F
Propane	Chemgas, Flamex	4.5/1	5130°F
Natural Gas	Flamex*	1.9/1	5040°F

**Flamex has been added to natural gas supply lines.*

FUEL EFFICIENCY

Fuel Types	BTU/Cu.Ft.		Oxy/Fuel Ratio	Fuel Use Factor	Oxygen Factor
	Total	Inner			
Acetylene	1470	507	1.5/1	1.0	1.50
MAPP	2406	517	3.5/1	1.2	4.20
Propylene	2371	379	3.5/1	1.2	4.20
Propane	2561	280	4.5/1	1.5	6.75
Natural Gas	1000	40	1.9/1	4.0	5.00

**Pertains to materials up to 2" thick. Heavier plate factors shift toward fuels with inner BTU.*

Adjusting For Maximum Flame Temperature

1. Light the torch and adjust to any desired flame setting.
2. Leaving torch fuel gas valve undisturbed, slowly close preheat oxygen valve until inner preheat cones become long and non-uniform in shape.
3. Slowly open preheat valve while paying close attention to the change in the inner cone length. They will shorten, remain the same length for a while, and then will begin to lengthen again as you continue to add oxygen.
4. Repeat steps 2 and 3 but this time stop opening the oxygen valve when the inner cones first become their shortest length. It is at this point that flame temperature and flame intensity are maximum.

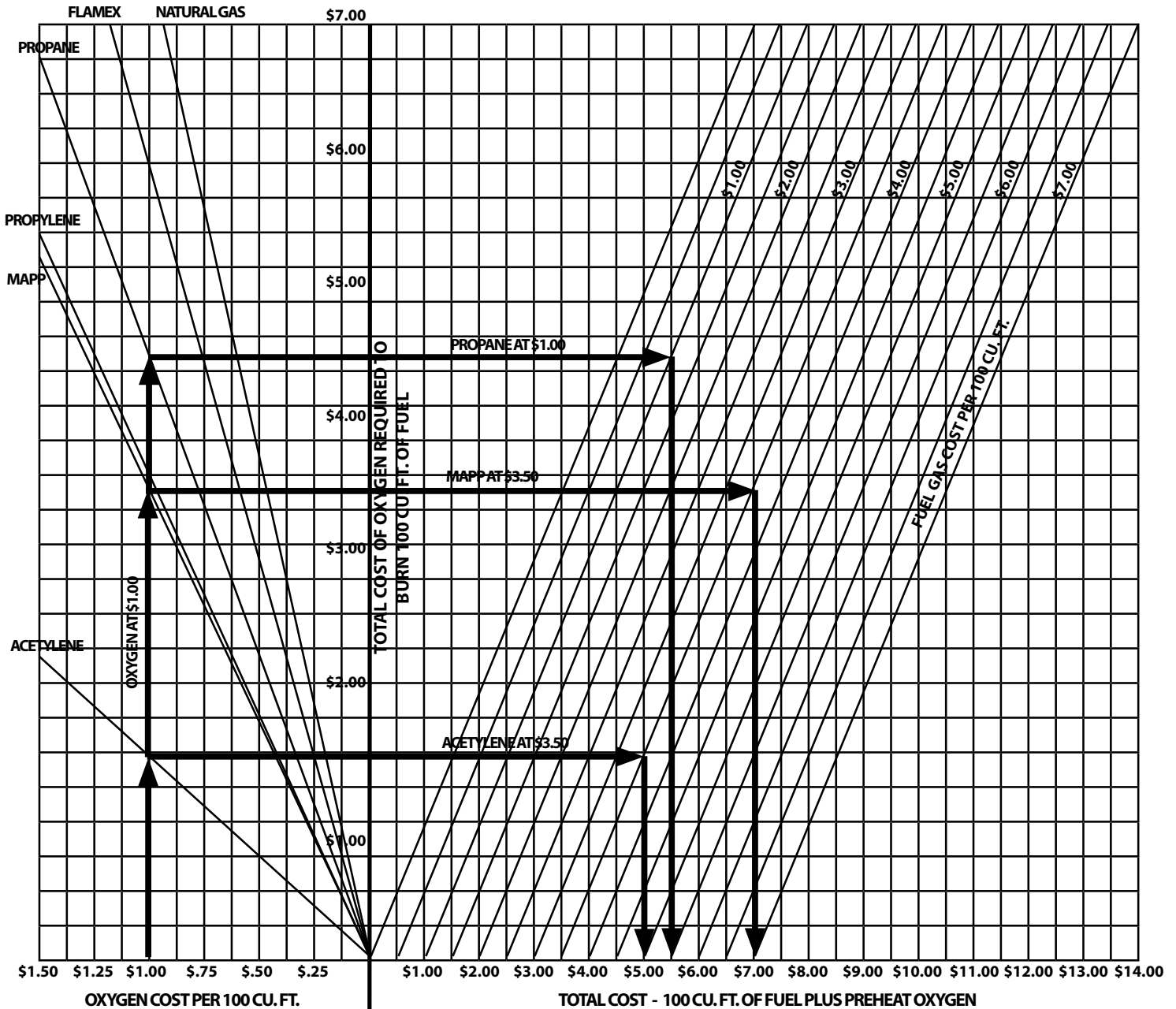


Figure 1: Preheat Flame Cost Calculation Chart

How To Use "Preheat Flame Cost Calculation Chart":

1. Enter chart at bottom left with oxygen cost per 100 cu. ft.
2. Move vertically along cost line until it intersects with angled line representing type of fuel being used.
3. Move to the right until it intersects the "FUEL GAS COST PER 100 CU. FT." line. Cost of preheat oxygen to burn 100 cu. ft. is read where the horizontal line crosses the major vertical axis.
4. Move vertically downward from "FUEL GAS COST PER 100 CU. FT." line to major horizontal axis where "TOTAL COST OF 100 CU. FT. OF FUEL AND PREHEAT OXYGEN" are read.

Effect Of Preheat On Cut Quality**Characteristics of Proper Preheat:**

1. Top edge quite square less than 1/16" melt over (top rounding).
2. Face of cut contains an easily removable thin layer of slag which covers a clean surface with well defined drag lines from top to bottom.
3. Little to no easily removable slag on the bottom edge.

Characteristics of Too Much Preheat:

1. Heavy roll over and occasional protrusion at top edge.
2. Black heavily crusted slag on face can be more difficult to clean to base metal.
3. Upper portion of cut has little to no drag lines and detail because of melting.

Characteristics of Too Little Preheat:

1. Top edge is almost perfectly square.
2. Torch is constantly on the verge of losing cut.
3. Some difficulty is experienced in getting through heavy plate (over 4").

General Comments / Recommendations About Fuel Gas:

1. If using cylinder oxygen, try to use a fuel with the lowest oxygen factor to minimize cost, cylinder handling and rental charges. See *"Preheat Flame Cost Calculation Chart"* on Page 8.
2. For very thin plate cutting (less than or equal to 1/4"), acetylene provides minimum plate distortion and cleanest cut because of high inner BTU and low total BTU.
3. All fuels produce the same quality of cut if adjusted properly on plates between 1/4" and 2" thick. Operating costs will vary however.
4. Acetylene becomes more difficult to use above 2" because of tendency to backfire and flashback during piercing.
5. As thickness increases, fuels with lower inner BTU content are preferred because they tend not to burn and round top edge of plate.
6. Five regulator preheat controllers should be on every steel service center machine. These permit intense flame adjustment during preheat/pierce and softer settings during cutting to maintain maximum quality and efficiency and to minimize cost.
7. Natural gas is the preferred fuel gas in areas where it is available. Low unit cost and good quality in all but very thin pieces. Cautions: Must have bulk oxygen, and natural gas supply pressure of 10 psi minimum. If lower, booster pumps should be installed. Good injector torches can improve performances below 10 psi. See *"Torch and Cutting Nozzles"* section beginning on Page 15.
8. Do not arbitrarily change fuel gas type without consulting present supplier to be sure correct torch and nozzles are being used. See *"Torch and Cutting Nozzles"* section beginning on Page 15.
9. Be skeptical of claims made by proprietary fuel gas suppliers for hotter flame temperature, faster cutting speed or better cut quality. Cutting speed on a thin plate (less than or equal to 1/2") is controlled by preheat intensity (flame temperature) and in heavier plate cutting by oxygen stream shape and quality, not the fuel type. Quality of cut is a function of oxygen stream and cutting speed.

Oxygen Stream: The Single Most Important Factor In Cut Quality

Desired Characteristics:

High Purity
High Pressure
Long Uniform Stream
Sized to Thickness Being Cut

Purity:

Quality Cutting	99.5% - 100% Purity
Decreasing Quality	99.5% - 95.0% Purity
Cutting Operation Ceases	95.0% and below

High Pressure:

High pressure is used to provide adequate quantities of oxygen to react sufficiently with a narrow band of steel and to blow slag clear of the cut.

Long Uniform Stream:

The stream must be columnar in shape and extend visibly for at least 6" in a nozzle test. Nozzle design, cleanliness of oxygen orifice, and operating pressure control stream quality.

Diameter Of Stream:

Consider oxy-fuel cutting as a saw cutting through wood. The volume of wood being removed per minute relates to the steel being removed in cutting. This relates to:

$$\text{Plate Thickness (in.)} \times \text{Cutting Speed (in./min)} \times \text{Cut Width (in.)} = \text{In.}^3/\text{min.}$$

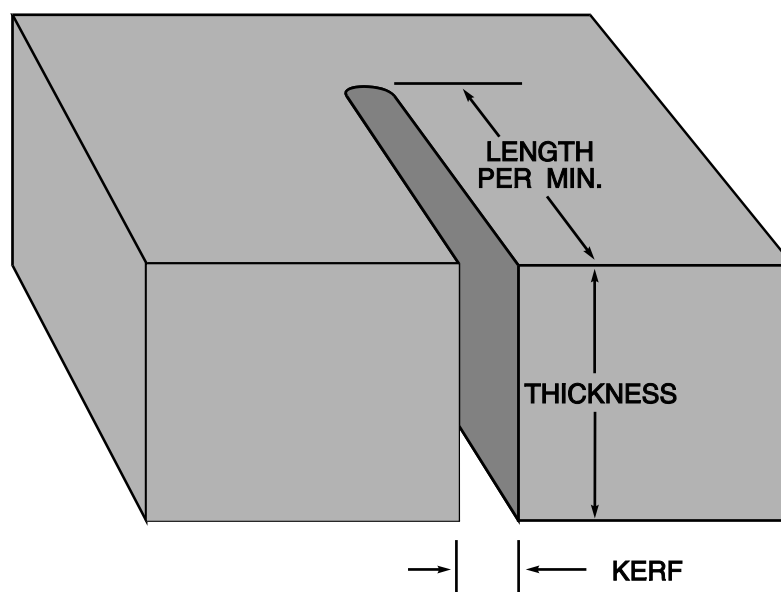


Figure 2: Cut Volume

As plate thickness increases, cut volume increases.

Thickness (in.)	Width (in.)	Speed (in./min.)	Cu. in./min.
0.5	0.055	20	0.55
1.0	0.070	18	1.26
2.0	0.090	11	2.16
4.0	0.120	08	3.84
8.0	0.160	05	6.40

Oxygen flow must increase at about the same ratio in order to oxidize the steel sufficiently or volume of cut must remain constant by lowering speed.

Example:

Use a 1.0 inch nozzle to cut a 4.0 inch plate:

Thickness (in.)	Width (in.)	Speed (in./min.)	Cu. in./min.
1.0	0.070	18	1.26
4.0	0.120	08	3.84

Smaller nozzles can be used to cut heavier thickness with dramatic reductions in speed and some possible increase in quality. The above example was exaggerated. Generally, only next smaller size is used.

Example:

Use a 4.0 inch nozzle to cut 1.0 inch plate:

Thickness (in.)	Width (in.)	Speed (in./min.)	Cu. in./min.
4.0	0.120	08	3.84
1.0	0.070	18	1.26

Unfortunately the above example will not achieve the desired results. The use of oversized nozzles produces a cut that has considerable cut face angle because the oversize oxygen stream expands as it passes through the plate. This results in the bottom of the cut being wider than the top.

Some speed increase can usually be obtained but face angle and quality of surface will suffer. It can be related to using a rip saw for a coping saw application. In the example above, nearly 250 ft.³ of oxygen per hour would be wasted.

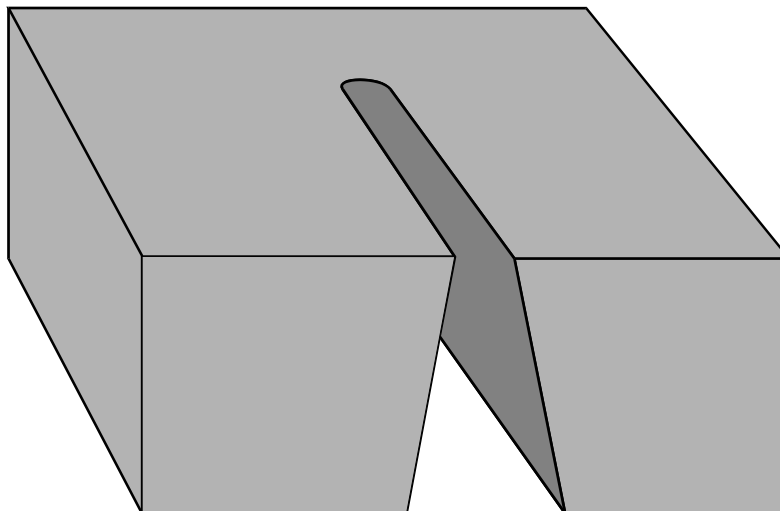


Figure 3: Result of Oversized Nozzle

What About Increasing Pressure?

The amount of oxygen flowing through an orifice is directly related to the change in absolute operating pressure.

Absolute pressure (psia) = Gauge pressure (psig) + 14.7

Increasing operating pressure from 60 psig to 120 psig has the following effect on oxygen flow.

$$\frac{120 \text{ psig}}{60 \text{ psig}} + \frac{15 \text{ (absolute)}}{15 \text{ (absolute)}} = \frac{135 \text{ psia}}{75 \text{ psia}} = 1.8 = 80\% \text{ more oxygen}$$

Unfortunately as the pressure goes up, the diameter of the stream increases even faster than the increase in oxygen flow. This increases the width of our cut and the resulting cut volume while providing less oxygen to oxidize the steel. This will result in loss of quality and speed.

Use recommended pressure setting.

Effect Of Bore Design And Oxygen Pressure On Cut Quality

Material: 1-1/2" Carbon Steel
 Travel Speed: 15 ipm
 Nozzle: Standard .052" Divergent Bore
 Oxygen Pressure:

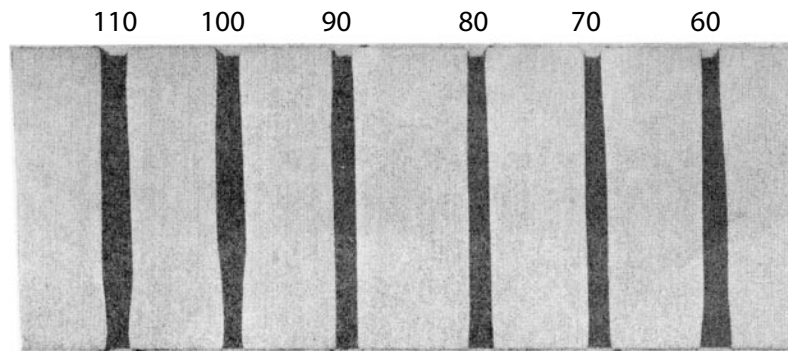


Figure 4: Cut Profiles with Varied Pressure

Effect Of Bore Diameter And O₂ Pressure On Cut Quality

Material: 1" Carbon Steel
 Travel Speed: 14 ipm
 Nozzle: Standard .060 inch Diameter Bore
 Oxygen Pressure, psig:

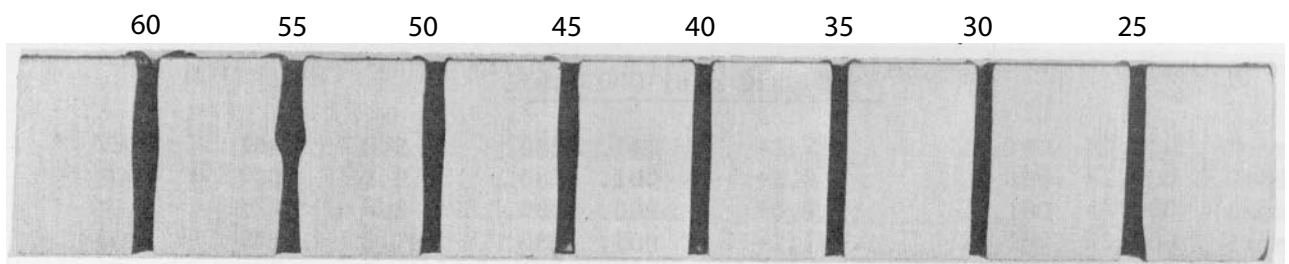


Figure 5: Cut Profiles With Varied Pressure, .06 Bore

Nozzle: Standard .04. inch Diameter Bore

Oxygen Pressure, psig:

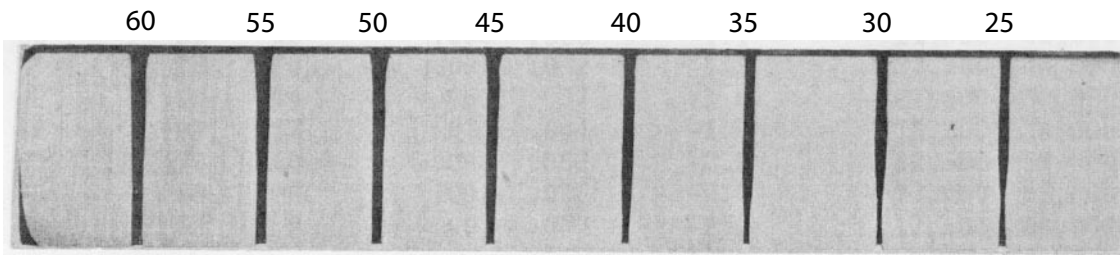


Figure 6: Cut Profiles With Varied Pressure, .04 Bore

General Comments / Recommendations About Oxygen Stream

1. Oxygen purity of at least 99.5% is a must. The purer the better.
2. Although bad oxygen purity is seldom the cause of poor cut quality, it should be tested as a last resort by operating from a different oxygen source. Bad purity is characterized by the inability to travel at recommended speeds and accompanied poor quality at virtually any speed.
3. Use manufacturer's recommended nozzle size and operating pressure for most predictable results.
4. One nozzle size smaller than recommended is sometimes used together with resulting slower speeds to achieve the very best quality. Unfortunately, this does reduce operating efficiency.
5. For high speed straight line stripping use 1 to 2 nozzle sizes larger than recommended. Angle torch forward about 30 to 45 degrees from vertical position and increase speed to the point where slag stream exits the bottom at vertical down direction. Quality will be less than what is normally accepted but speed will be substantially higher than normal.

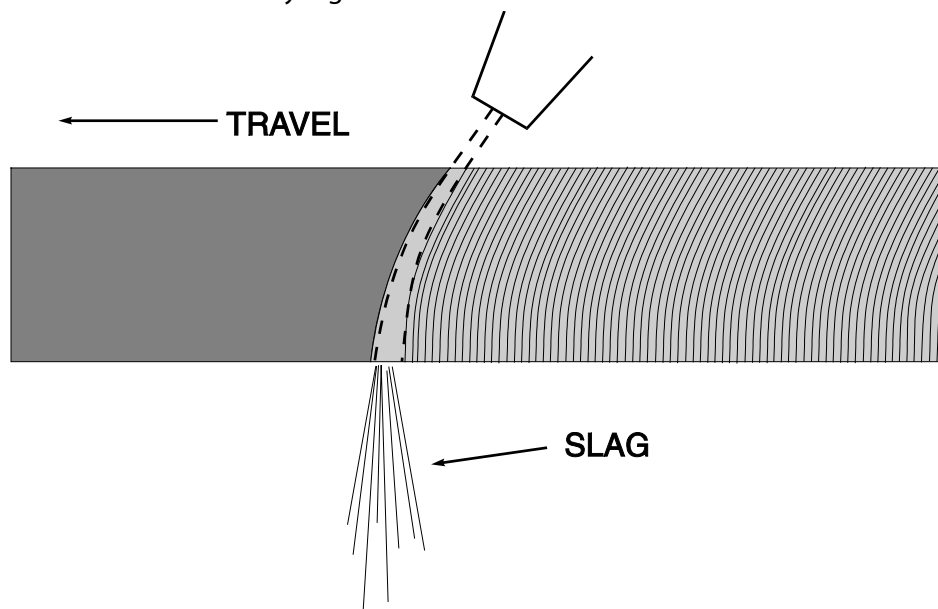


Figure 7: High Speed Stripping

Torch**Variations**

- Length
- Number of Hoses and Valves
- Mixing Device and Capacity

Lengths will vary from approximately 5 inches long on bevel units and small portable machines to 20 inches long on industrial shape cutting machines. There is no impact on cut quality, but perhaps capacity limit.

Some torches do not contain any valves. These are used in combination with other pieces of apparatus like bevel units which themselves contain valves for adjustment. There is no impact on cut quality.

The number of hoses depends upon whether there are separate regulators for preheat oxygen and cutting oxygen or they are both operated from one source. All industrial grade machines have three hose torches for separate control. Two hose torches can starve preheat oxygen in heavy thickness with resulting loss of quality. This can greatly reduce capacity.

Mixing Devices**Equal Pressure Mixer**

Equal pressure mixer (approximately 5 psig fuel and oxygen at the mixing device).

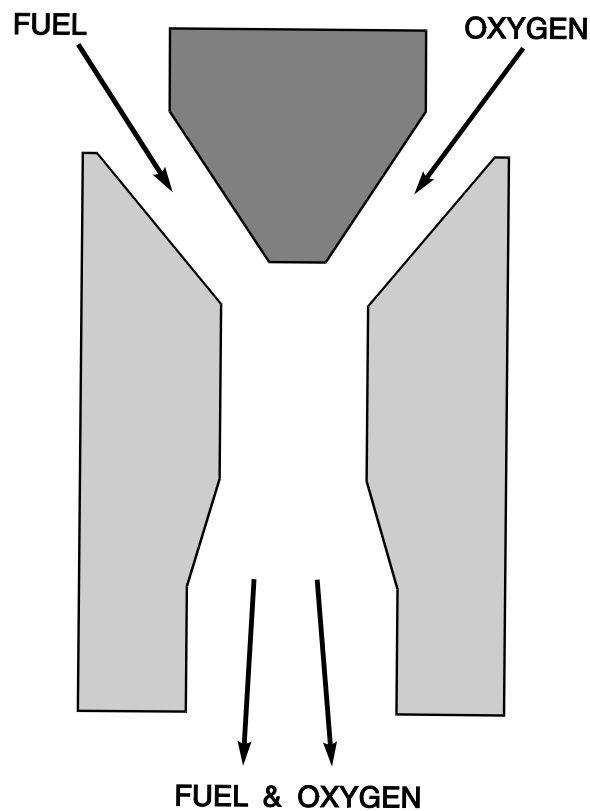


Figure 8: Equal Pressure Mixer

Advantages

- Simple device
- Use with any fuel

Disadvantages

- Difficult to balance flames and oxygen ratios in multiple torch installations (cutting machines).

SECTION 4

TORCH AND CUTTING NOZZLES

Injector (Low Pressure Mixer)

Injector with 0 - 5 psig fuel and 10 - 50 psig oxygen

Advantages

- Can be used with any available fuel pressure. Easily balanced in multiple torch operations.

Disadvantages

- Must be chosen based on type of fuel gas being used and the thickness range to be cut.

Example:

Low Pressure, Medium Capacity Natural Gas
(<3 psig) (2" capacity)

Low Pressure, Medium Capacity Natural Gas
(3 - 10 psig) (8" capacity)

Medium Pressure, Medium Capacity Natural Gas
(3 - 10 psig) (18" capacity)

Medium Pressure, High Capacity Natural Gas
(3 - 10 psig) (> than 20" capacity)

Proper choice of injector is a trade off between balance of torches and capacity.

Choice of too *large* an injector can result in poor torch balance if plate thickness is too small.

Choice of too *small* an injector can result in long preheat time because of inability to burn enough fuel and oxygen to preheat the plate surface quickly.

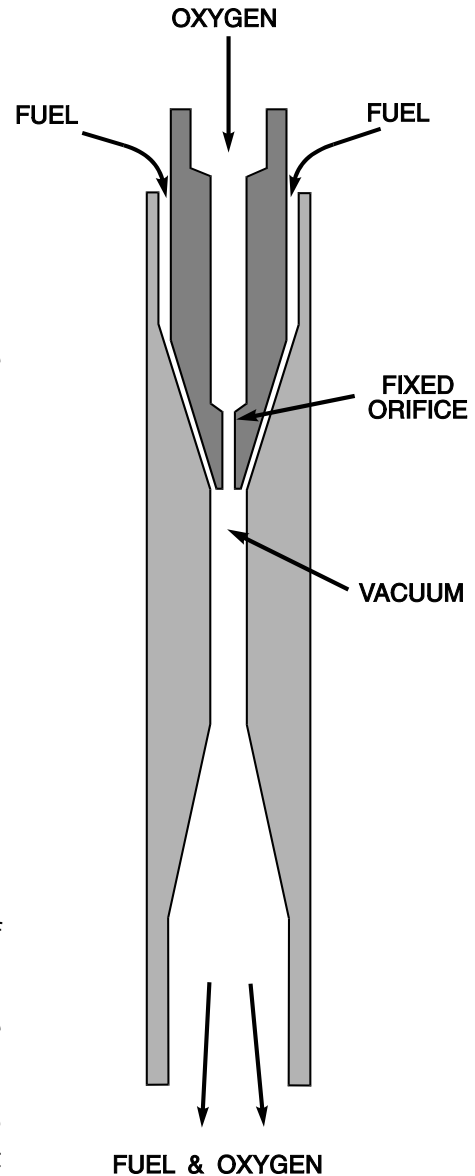


Figure 9: Injector

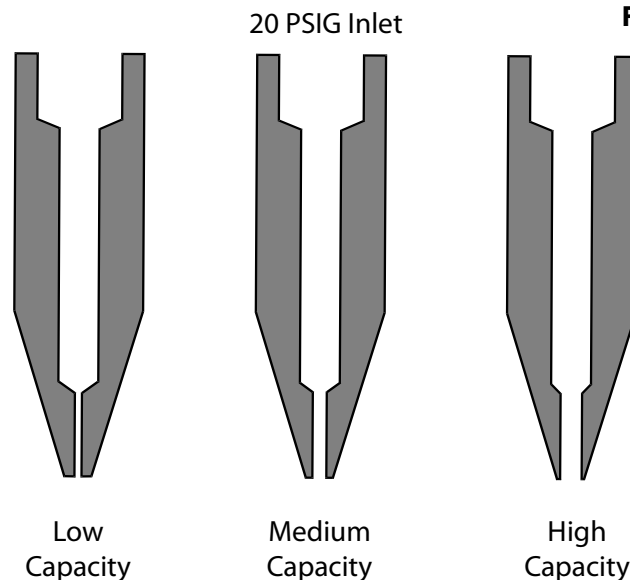


Figure 10: Injector Orifice Sizes

Cutting Nozzles

Principle Elements

Preheat Design

Oxygen Bore Design

Nozzle Types

Fuel Gas Type

1-pc/2-pc

Standard Pressure/High Pressure
(High Speed)

Special Function (high preheat, gouging,
strip, sheet metal, etc.)

Fuel Gas

Acetylene

All Other Fuels

No. Pieces

1-pc only

2-pc/1-pc

Pressure

Std and High

Std and High
(high durability)

Remarks

2-pc performance

1-pc recommended for hand cut

2-pc provides best flame intensity,
less durable. Recommended for
machine cutting.

Preheat & Design

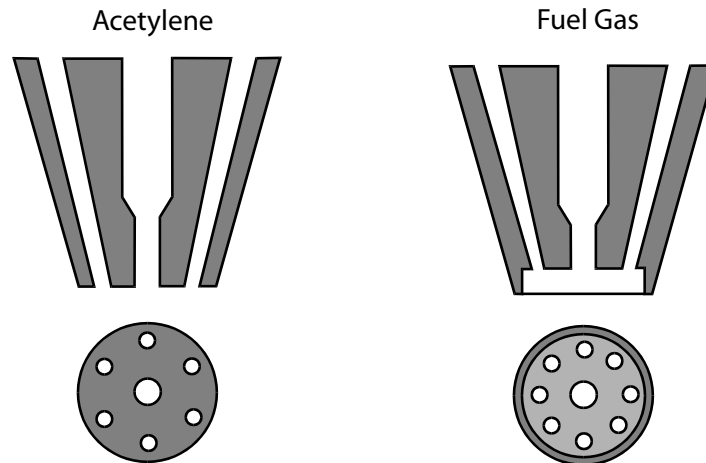


Figure 11: Nozzle Preheat Designs

Acetylene Nozzles (Fast Flame Burning Rate)

Flush face.

Flame holds on to face easily.

Fast burning rate tends to cause backfire/flashback.

Best efficiency with 1-pc design.

Fuel Gas Nozzles (Slower Flame Burning Rate)

Recessed face as flame holder.

More difficult to ignite.

Little to no tendency to backfire/flashback.

Best efficiency with 2-pc design.

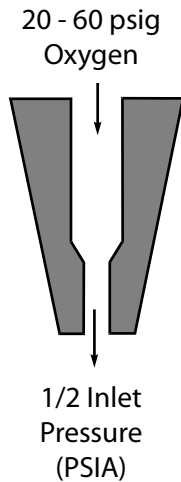
Depth of recess varies with fuel.

Preheat design has little effect on cut quality other than top edge. Improper design can cause lengthening of time to preheat. Some capacity limit if preheat flame is too small.

Oxygen Bore Design

This Is The Most Important Factor In Cut Quality!

Standard Pressure Bore Design



Principle Uses

Hand Cutting
Machine Cutting (by unskilled operator)

Advantages

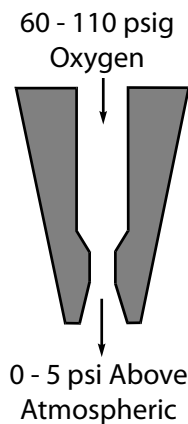
- Easy to clean
- Low pressure operation (less slag blow)
- More forgiving

Disadvantages

- 10 to 15% slower speed than high pressure designs

Figure 12: Straight Oxygen Bore

High Pressure (High Speed) Bore Design



Principle Uses

Machine Cutting single and multiple torch

Advantages

- 10 - 15% higher speed than standard pressure designs

Disadvantages

- More difficult to clean
- Special cleaning tools recommended

Figure 13: Divergent Oxygen Bore

Nozzle Cleaning

Because of the precision design of high speed nozzles care must be taken in cleaning them so as not to destroy the geometry.

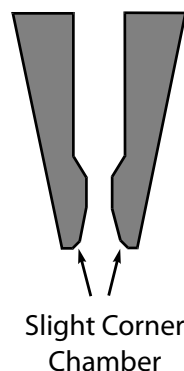


Figure 14: Deburring Exit Corner

Cleaning Procedures

Straight Throat - Use smooth wire of suitable size and insert to remove loose debris. Barbed wire may be used but it should be inserted straight and not in a sawing fashion. The key is not to remove metal.

Tapered Divergency - Special tools are available from most manufacturers for cleaning these tapers. These are intended to burnish the surface in order to remove debris and not metal. A simple cleaning device is a round wooden tooth pick inserted into the orifice and twisted between the fingers to conform to the shape.

Exit Corner - Frequently burrs will be created at the exit corner of the oxygen bore because it tends to heat up more and accumulate slag. The use of a 1/4" diameter 3-flute 90° counter sink can help to prevent this. Simply hold the counter sink between thumb and forefinger, insert into mount of orifice and spin gently. This will put a very fine 45 degree chamfer around the orifice to reduce its tendency for burrs and improve resulting cut quality.

Effect Of Oxygen Bore Condition On Cut Quality

1. Dirty or damaged oxygen bore will result in a non-uniform cutting stream. This will cause defects such as undercutting (belly) in the cut face.
2. In shape cutting this will cause defect intensity and location to change around the circumference of a part.

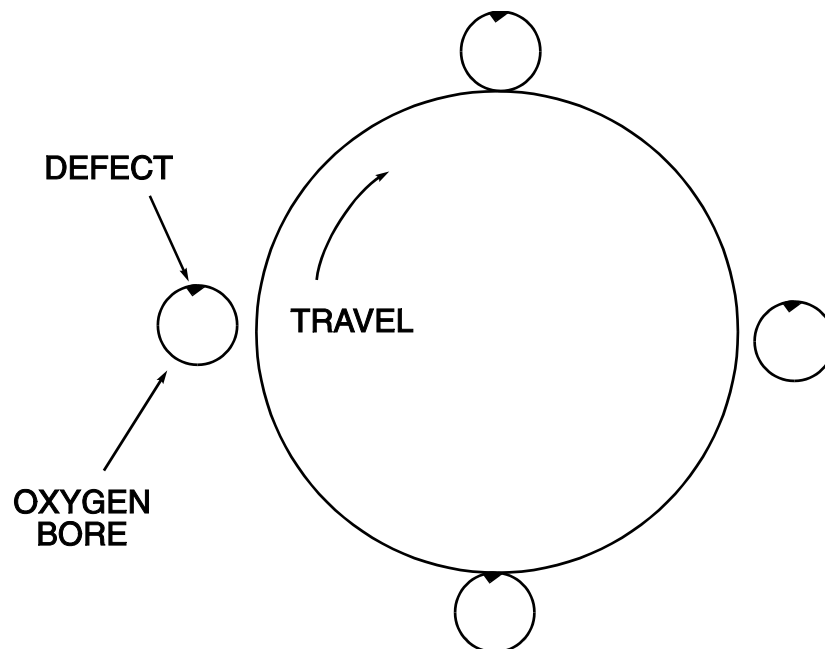


Figure 15: Effect of Defects in Oxygen Bore

3. To correct above defects make sure speed, nozzle size, and oxygen pressure are as recommended by manufacturer. If no improvement, change to nozzle of known good quality or reduce travel speed accordingly.

Speed Ranges - Cutting charts are available from the manufacturer for most cutting nozzles. The speed of cut is either presented as a single range or broken up into categories such as "High Quality", "Quality", and "Rip Cut".

Effect Of Cutting Speed On Cut Quality

1. Within cutting ranges for each thickness, quality increases as speed is decreased. This is because higher levels push the ability of the cutting bore/stream to deliver the full amount of high purity oxygen with the perfect stream geometry to the kerf. Under normal conditions, maximum listed speeds cannot be achieved without some sacrifice in quality. Manufacturers are optimists.
2. As speed increases, drag lines lean further to the rear. This results in some rounding of the bottom edge in shape cutting.
3. At higher speeds, undercuts or bellies will appear along the cut face destroying the desired flatness.
4. At extreme speeds, the drag will be so severe that the bottom corner of the cut will not be completed at the finish of the cut. We call this a sever cut. Quality is not important.
5. Slow speeds can cause problems as well. The availability of too much oxygen can cause instability of operation when not enough cutting action is created at the leading edge. Remember, all cutting action takes place on the front half of the stream where it contacts the metal. Instability can cause gouges in the face of the cut, usually near the bottom.
6. When cutting heavy plate (greater than or equal to 8"), the majority of the heat being generated during cutting comes from the exothermic reaction between oxygen and iron and only a small percentage from the preheat. The opposite occurs when cutting thin plate.

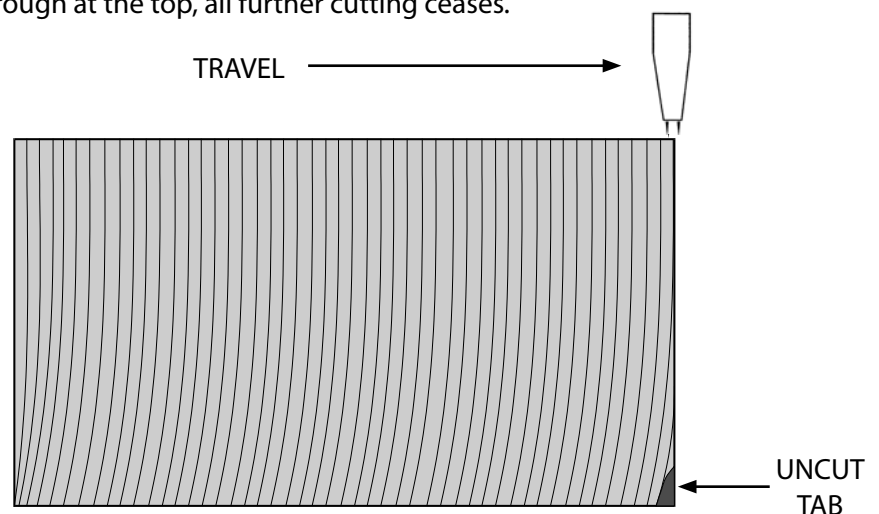
The stability and uniformity of the cutting reaction depends upon the heat generated by oxidation as the molten slag runs along the leading edge of the oxygen stream as it passes through the plate thickness.

If travel speed is too slow, the amount of metal volume being oxidized and the heat being generated is insufficient to maintain the cutting operation through the plate thickness. This will also frequently cause a gouge in the cut face and sometimes not fully penetrate.

Conversely if speed is too high, large amounts of heat are generated. However, there is now not enough oxygen to handle the greater volume of metal which must be oxidized for the cut to be successfully completed. As a result the operation also pockets and terminates.

7. In very heavy plate cutting (larger than 10"), it is not uncommon to leave an uncut tab or bridge at the bottom end of the cut. This is the result of the drag in the cutting operation which causes the oxygen bore to clear the final corner at the top of the plate before the stream reaches the bottom corner. Once the stream breaks through at the top, all further cutting ceases.

**Figure 16:
Thick Plate Cutting**



Effect Of Travel Speed On Cut Quality

Material: 1/2" Carbon Steel
 Nozzle: Standard .031" Divergent Bore
 Oxygen Pressure: 75 psig
 Oxygen Flow: 64 cfh

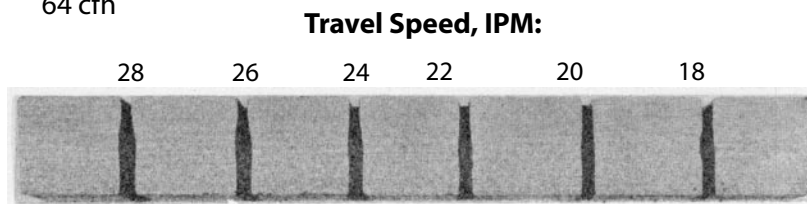


Figure 17: Cut Profiles with Varied Travel Speed, 1/2" Thick

Effect Of Travel Speed On Cut Quality

Material: 1" Carbon Steel
 Nozzle: Standard .069" Diameter Bore
 Oxygen Pressure: 40 psig

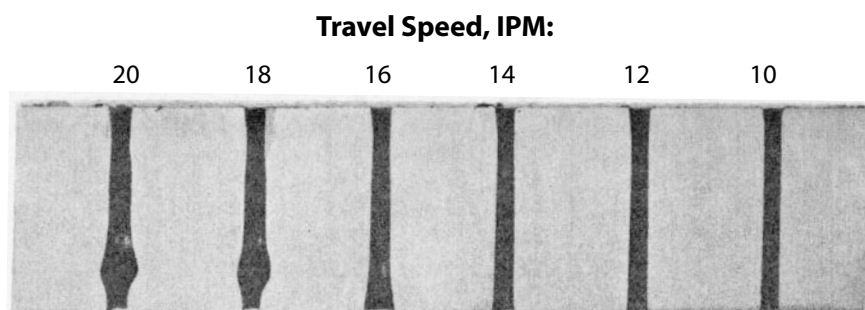


Figure 18: Cut Profiles with Varied Travel Speed, 1" Thick

Effect Of Travel Speed On Cut Quality

Material: 1-1/2" Carbon Steel
 Nozzle: Standard .052" Divergent Bore
 Oxygen Pressure: 70 psig
 Oxygen Flow: 165 cfh

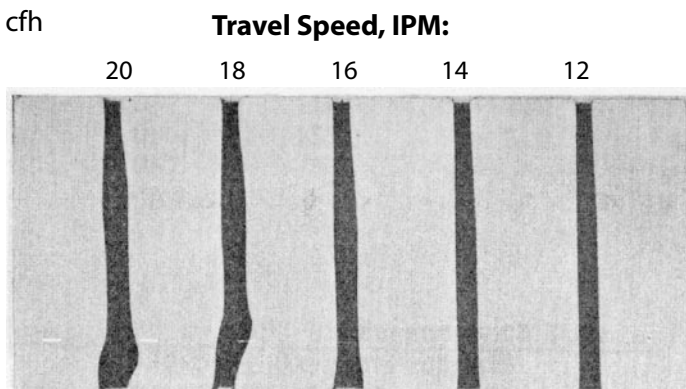


Figure 19: Cut Profiles with Varied Travel Speed, 1-1/2" Thick

Effect Of Travel On Stream Contour

Nozzle: 1502-6

Oxygen Pressure: 40 psig

Travel Speed: 12 ipm

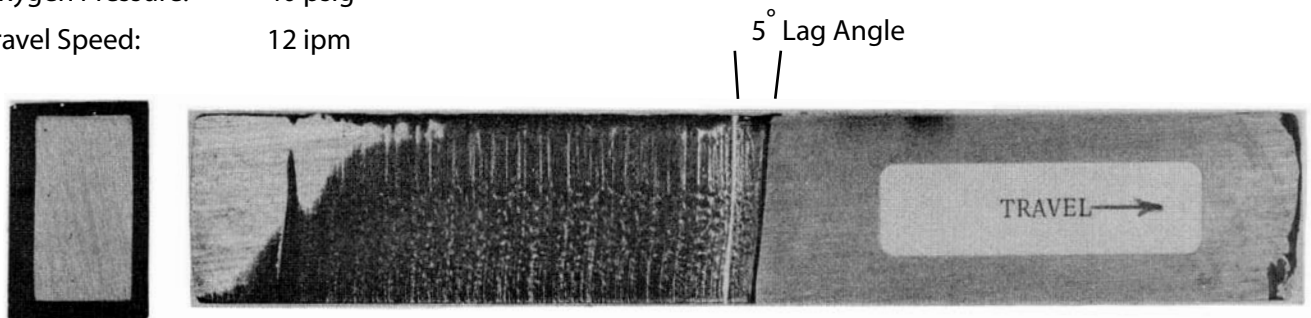


Figure 20: Cut Face at 12 ipm

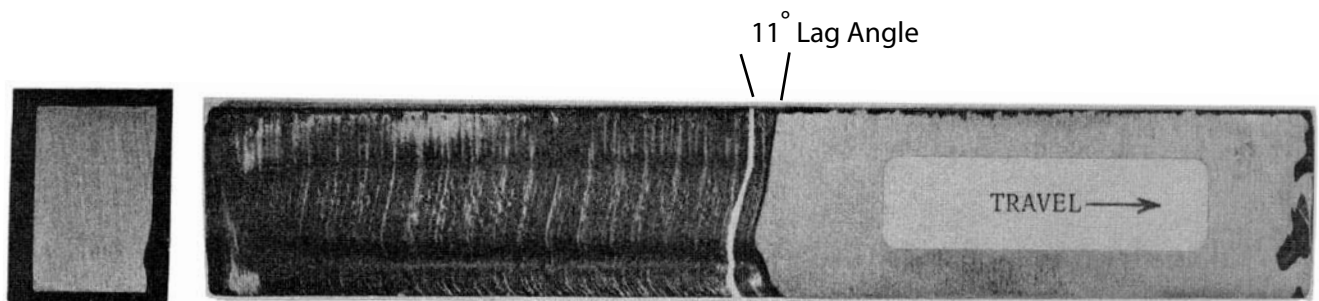


Figure 21: Cut Face at 20 ipm

Heavy Plate Cut Quality

Nozzle: Exp. 0.110" x .140" Divergent Bore

Oxygen Pressure: 90 psig

Travel Speed: 4-1/2 ipm

Material: 11-1/2" Carbon Steel

Oxygen Flow: 1000 cfh

Lag Angle: 2.0°

Top Kerf Width: 0.182 in.

Bottom Kerf Width: 0.299 in.

Kerf Angle: +0.5° incl.

Q/A, Ft³/hr/in₂

Kerf: 28,500

Throat: 97,000

Cut Quality Excellent

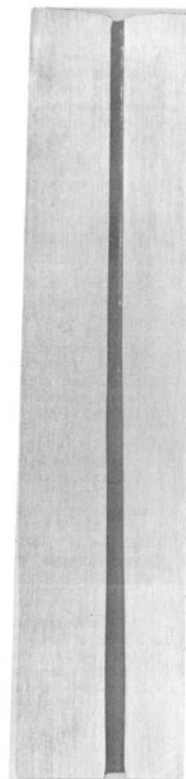


Figure 22: Heavy Plate Cutting

Plate Chemistry

Alloying elements such as carbon, nickel, chromium, manganese and silicon can have a noticeable effect on oxy-fuel cutting even when concentrations are very low.

Each of the elements act as contaminants in the plate. They present concentration that is not easily oxidized and, in doing so, upset the smooth formation of the slag stream.

Typically, the elements will be in varying concentrations throughout the plate and will cause erratic operation of the cutting process.

As alloying elements increase in concentration:

1. Roughness of cut and drag lines will also increase. Loss of cut frequency will increase.
2. Usable cutting speed will slow because of reduced oxidation.
3. Preheat intensity needs to be increased to compensate for loss of oxidation heat. Top edge rounding is more difficult to control without risking frequent loss of cut.

Poor Quality Plate

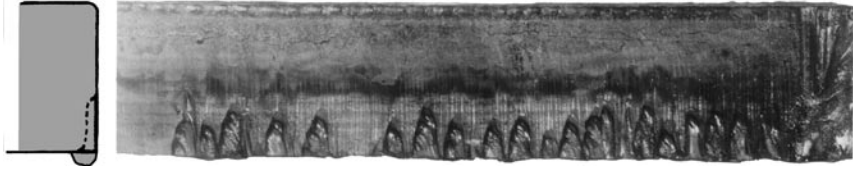
Heavy mill scale and rust require stronger preheat to penetrate the protective surface which is less reactive to oxygen. The scale sometimes creates an air gap between itself and the plate which can cause difficulties in maintaining the leading preheat. This is particularly so in thinner plate up to 1/2" thick. Heavier preheat or slower speed are the remedies with the resulting top edge rounding.

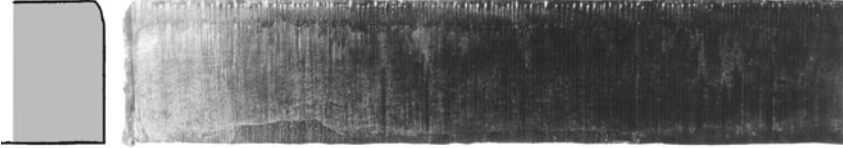
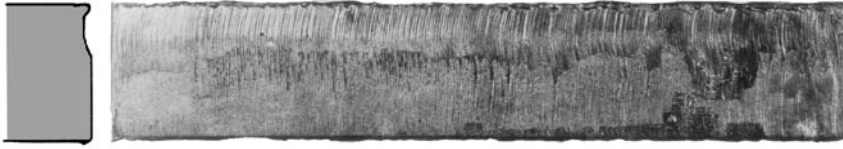
Laminated plate and plate with inclusions are the burner's worst enemies. Both defects will act as barriers to the continuous oxidation reaction within the plate with resulting instantaneous rooster tailing and loss of cut. If the burner suspects poor quality he can increase preheat and reduce speed. These will have some detrimental effects on overall quality but will reduce the likelihood of loss of cut. Laminated plate can make piercing of heavier sections virtually impossible because of the thermal barrier which it presents deep within the plate.

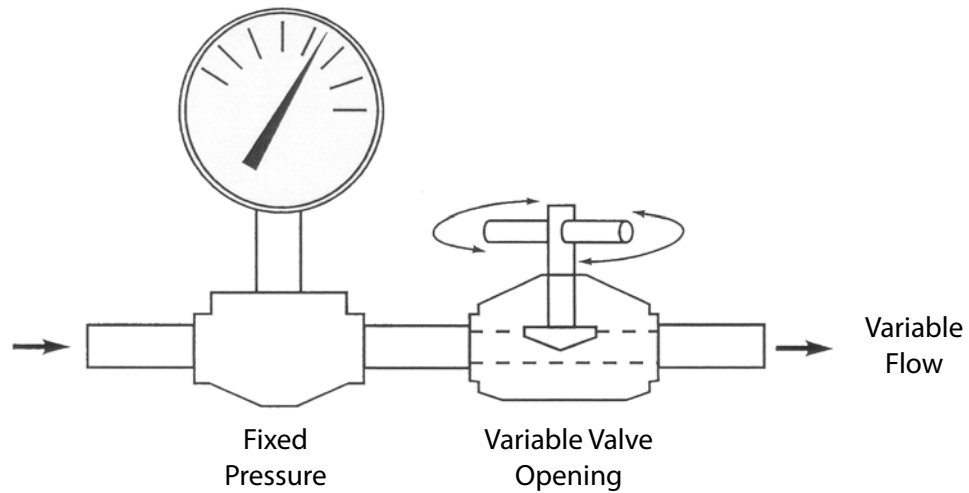
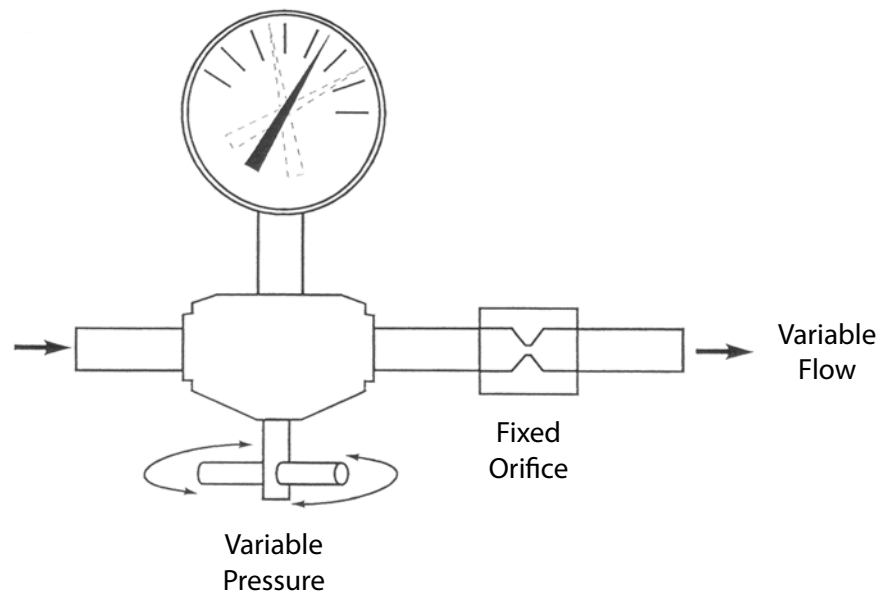
Oily Plate

Oil has little negative effect on performance and cut quality. Other than a slight speed reduction in very thin material and the production of smoke there is little impact.

7 Faults of Oxy-Fuel Machine Cutting

1. Correct Cutting Technique The cut surface is smooth and square, and the kerf walls are parallel. The lag lines are almost vertical. There is little slag adhering to the bottom edge. The top edge is slightly rounded when the preheat flames are properly adjusted. This surface is ideally suited for many applications without further treatment.	
2. Cutting Speed Too Low An abnormally low cutting speed results in heavy gouging of the cut surface and slag adhering in large globules. Under this condition, oxygen and fuel gas are being wasted.	

3. Cutting Speed Too High An extremely high cutting speed results in heavy lag, as shown by the curved lag lines on the cut surface. The face is reasonably smooth but somewhat concave. Slag will adhere during cutting, but it may be removed with ease. Heavy lag cutting is recommended for straight line cuts only.	
4. Nozzle Too Far From Surface When carrying the nozzle too high above the work, excessive rounding of the top edge occurs. Also, the cutting speed may have to be lowered. With the correct nozzle clearance, the preheat flames should not be over 1/4" above the top surface of the work.	
5. Nozzle Too Near Surface When the nozzle is carried too low, part of the preheat flame's inner cones become buried in the cut kerf. This produces grooves in the cut face and excessive melting of the top edge. Also, the flame becomes subject to popping and lost cuts may result.	
6. Excess Cutting Oxygen If the cutting oxygen pressure is too high or the nozzle size too large, a reduction in cut quality will result. Nozzles are made to operate within a limited range of torch pressures. Therefore, excessive oxygen pressure causes distortions in the oxygen stream once it leaves the nozzle.	
7. Excess Preheat Flame Inexperienced operators often try to increase cutting speeds by using a heavy preheat flame. Excessive preheat causes melting of the top edge and may actually lower the speed of cutting. In addition, oxygen and fuel gas are wasted.	
8. Dirty Nozzle Used The nozzle has been fouled by some adhering scale causing the oxygen stream to lose its parallel form. The cut surface is no longer smooth and square and proof of pitting, under-cutting, heavy slag and scale is evident. The nozzle should be cleaned with care, so as not to distort, or bell-mouth, the cutting oxygen bore.	

Ways to Control Gas Flow**1. Fixed Pressure + Variable Orifice****Figure 24: Gas Flow Control - Fixed Pressure + Variable Orifice****2. Variable Pressure + Fixed Orifice****Figure 25: Gas Flow Control - Variable Pressure + Fixed Orifice**

Cylindrical Nozzle Design

A simple cylindrical metering orifice. These are operated at 25 - 60 psig depending on manufacture.

Divergency

The tapered part of the oxygen bore directly behind the throat in high pressure (high speed) nozzle designs. The divergency allows the high pressure to become close to atmospheric before it leaves the nozzle. This increases stream velocity and improves cut quality by keeping stream uniform. The increased velocity produces 10 - 15% higher cutting speeds.

Drag

The deflection in angle degrees that the cutting process assumes as it passes through the plate. Drag will increase and decrease with varying conditions such as speed, oxygen pressure, plate thickness, oxygen purity, etc.

Fuel Efficiency

The factor relating to the volume of fuel (in cu. ft.) needed to duplicate the efficiency of acetylene (is designated as 1.0 ft³).

High Speed Nozzle Design

Operates between 60 - 110 psig depending upon brand. Uses high pressure and divergency to produce 10 - 15% faster cutting speeds.

Kerf

Opening through the plate where metal is removed during the oxy-fuel cutting operation.

Oxygen Bore

The orifice in the cutting nozzle through which oxygen is directed at the plate for cutting. It controls the amount of oxygen consumed during cutting.

Oxygen Factor

The fuel efficiency times the oxy/fuel ratio for a given fuel to determine the multiples of oxygen needed to duplicate the performance of acetylene. The acetylene/oxygen factor is 1.5.

Oxy/Fuel Ratio

The relationship of cu. ft. of oxygen to cu. ft. of fuel gas mixture necessary to achieve maximum flame temperature. This ratio varies with fuel characteristics.

Slag

The oxidized iron that is produced during the cutting operation. Some may adhere to bottom edge of cut. Ease of removal is related to thoroughness of oxidation. Less oxidation generally makes slag more difficult to remove-reducing speed usually helps.

Throat

The cylindrical part of the orifice which controls the quantity of oxygen which is consumed.

Oxy/Fuel Flame Balance Procedure

The following procedure is used to balance multi-torch oxy-fuel cutting machines to insure that volumes and ratios of fuel and oxygen to all torches are similar. This will provide uniform preheat flames for piercing and cutting. This procedure applies only to OXWELD® torches of the model and type listed below. The use of other makes and types may not produce similar results.

For Use with Acetylene: OXWELD® C-37 Machine Torch

For Use with Fuel Gas*: OXWELD® C-67 Machine Torch

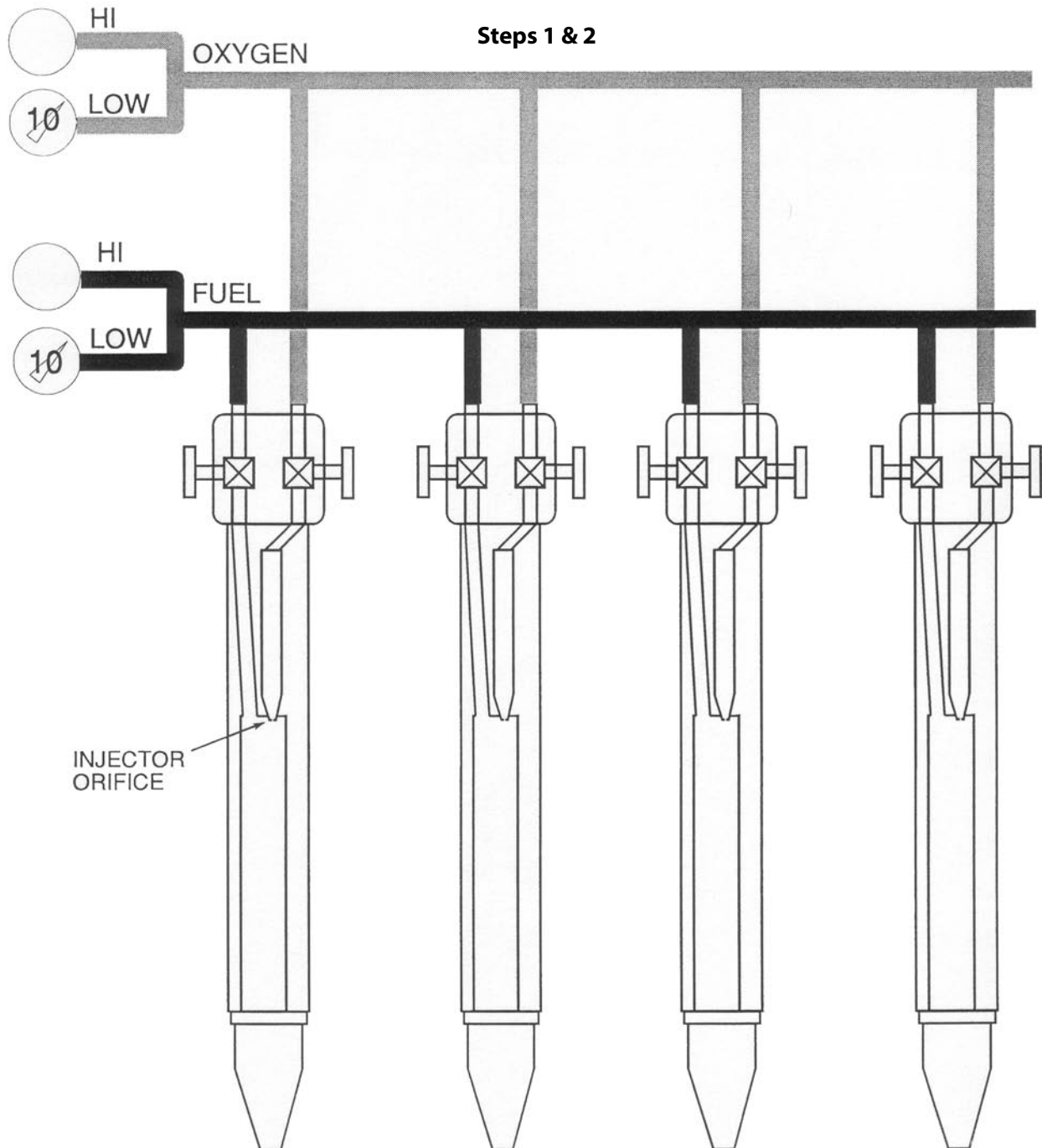
01Y56 - Injector preferred.

01Y61 - Only if fuel pressure is less than 2-3 psig at the regulator inlet.

**Natural Gas, Propane, Mapp FG-2 And Most Other Brand Name Fuels.*

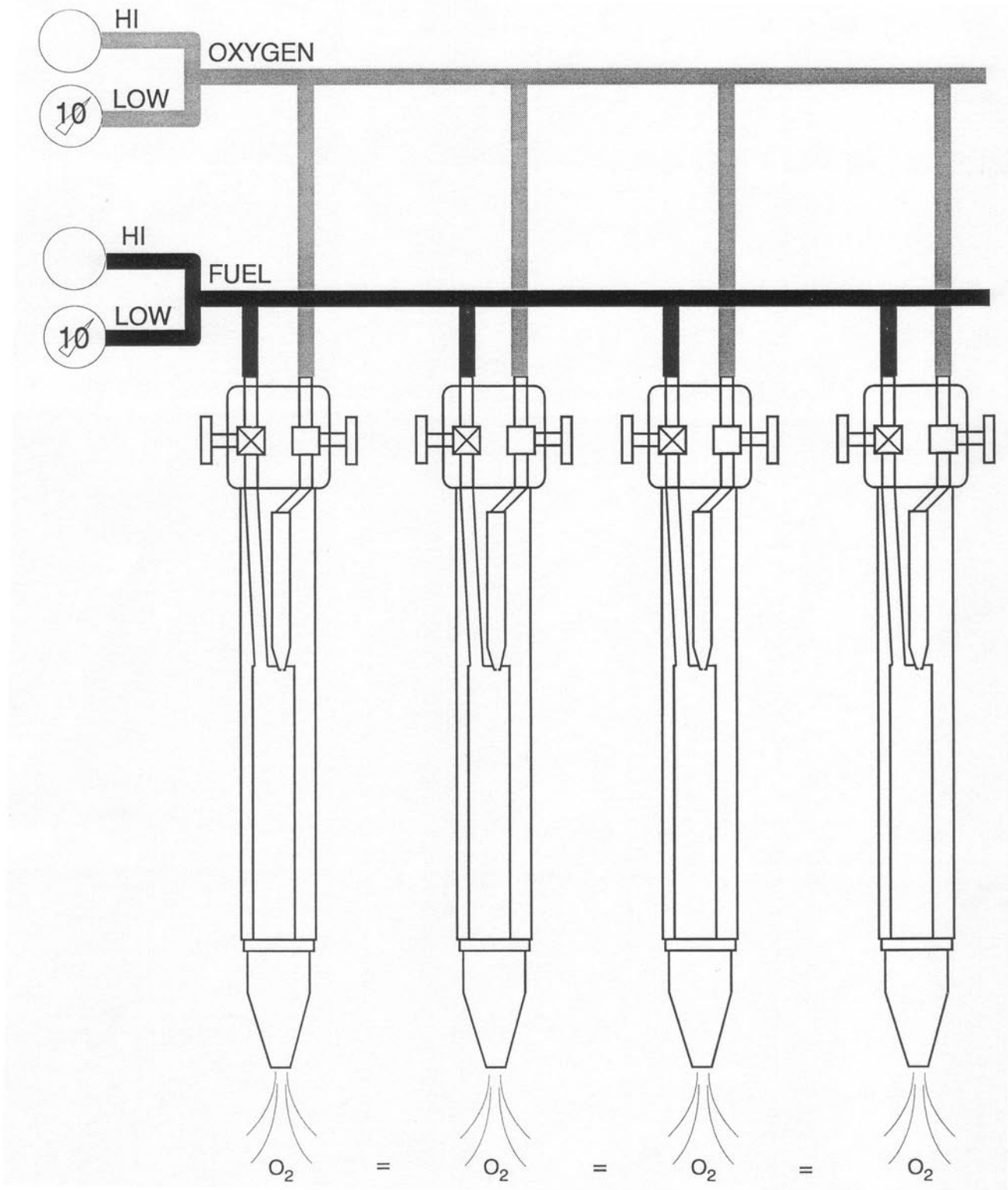
Procedure

If using a three regulator system or a five regulator system, the basic procedures are identical. With a five regulator system, however, the procedure is performed first with the low pressure regulators and after balancing, the high setting is established.

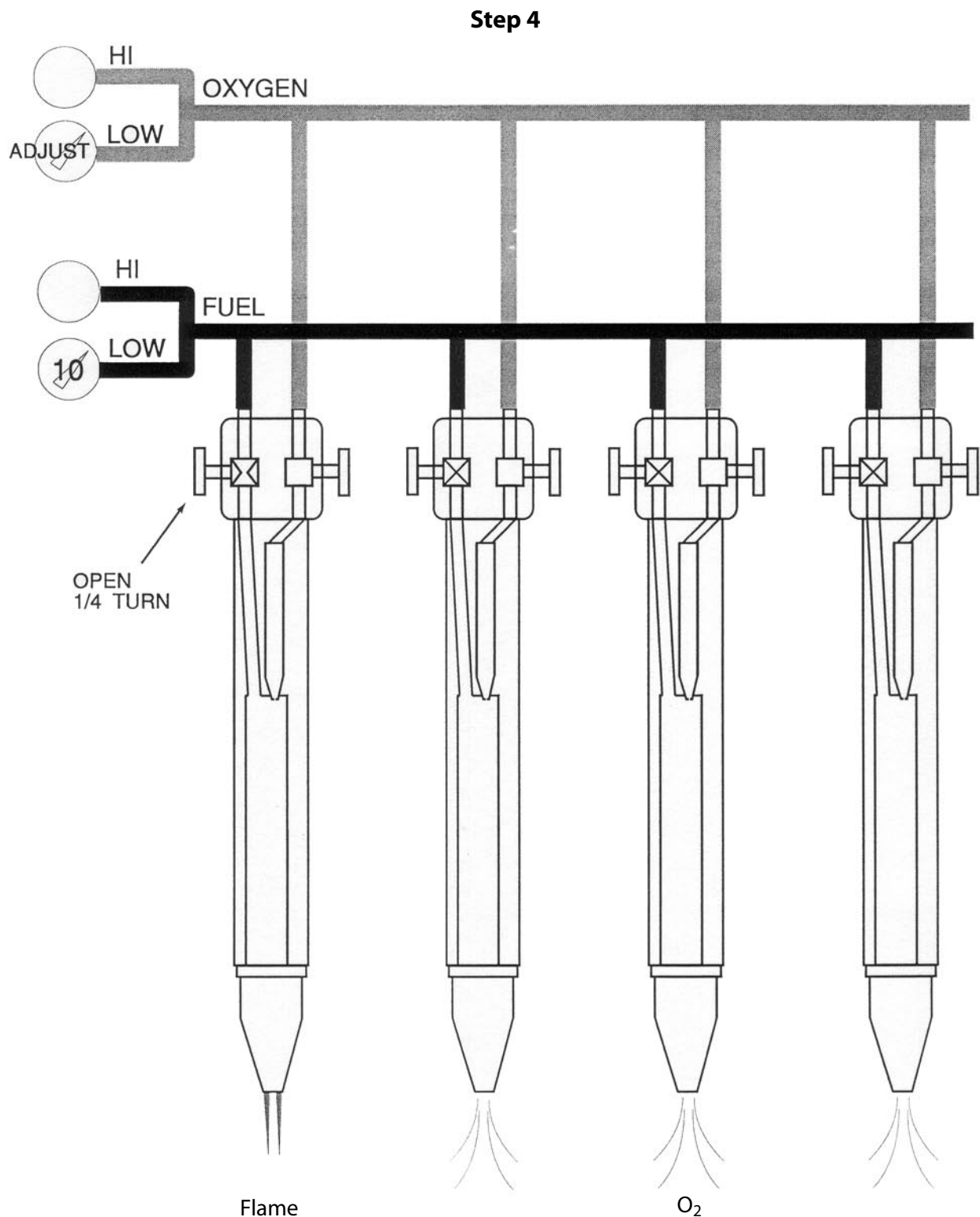


1. Actuate low pressure preheat oxygen regulator and adjust to 10 psig with *all* torch valves closed.
2. Adjust low pressure fuel gas regulator to 10 psig or the maximum that can be reached (which ever is less). Fuel gas torch valves are all still closed.

Step 3

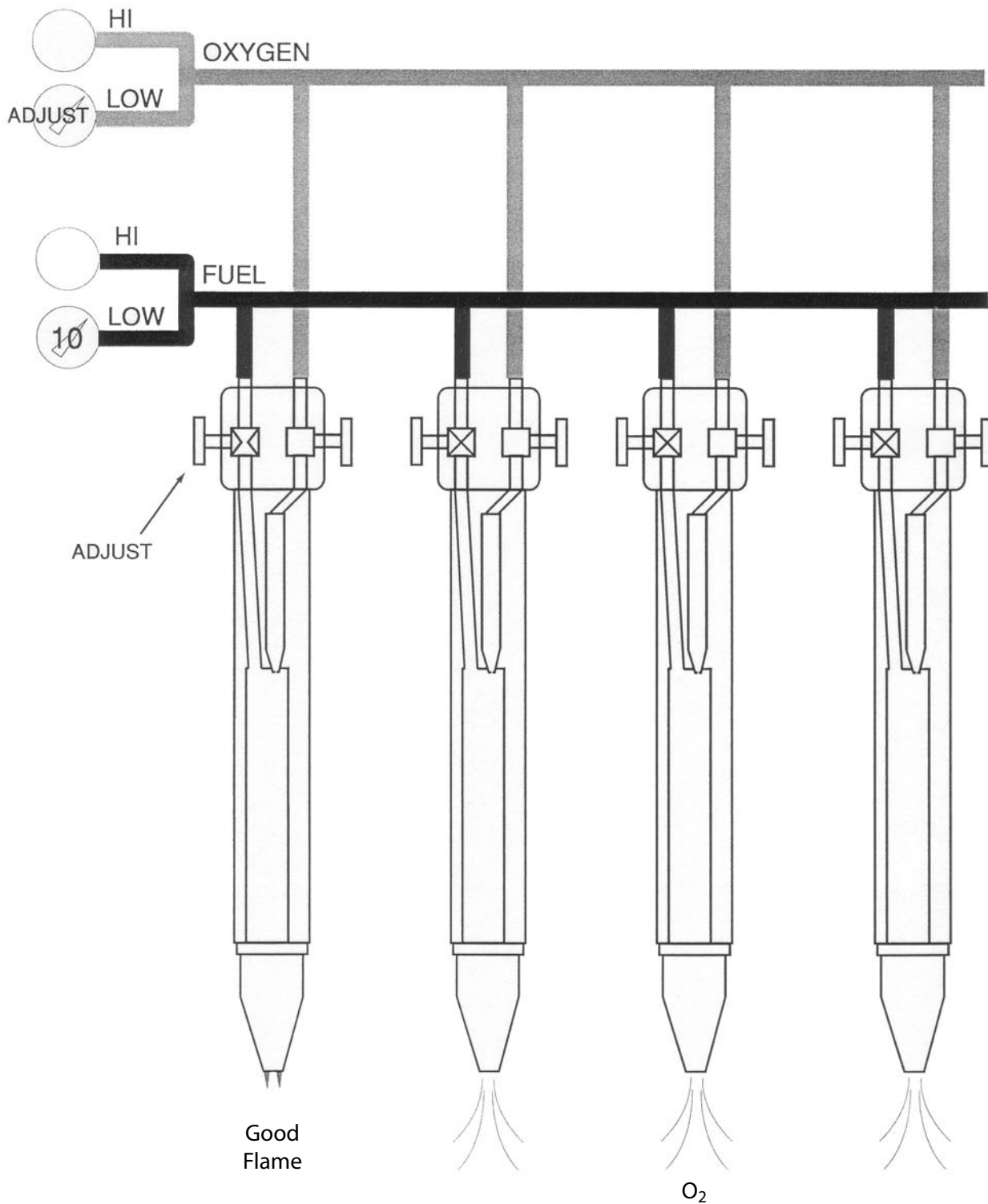


3. Open all preheat oxygen torch valves fully. The design of the torch/injector insures that the same amount of oxygen is now flowing through all torches.

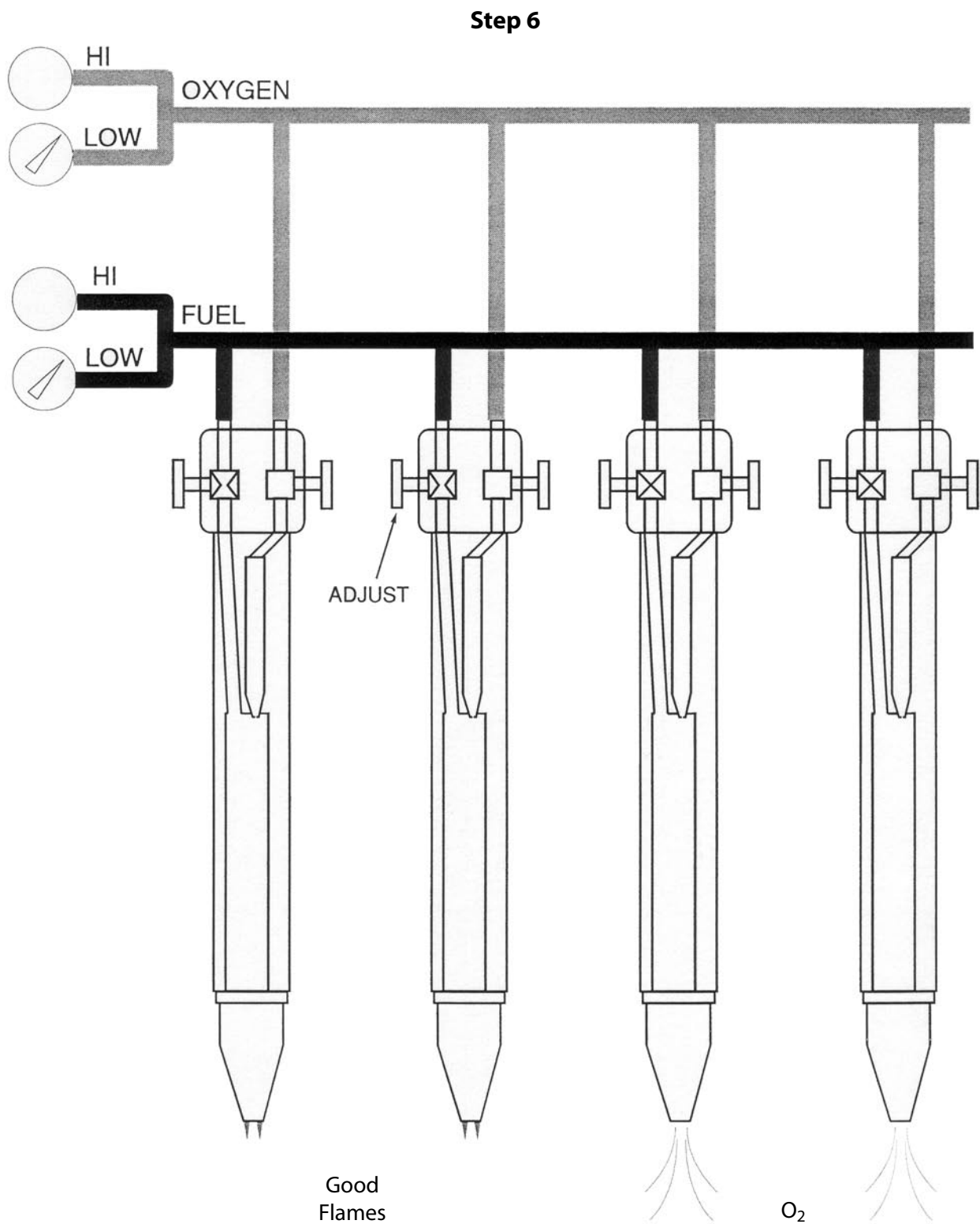


4. With preheat oxygen still flowing through all torches, open the fuel gas valve on the torch closest to you about 1/4 turn and light the flame. If it will not light, adjust fuel gas valve and/or low pressure preheat oxygen regulator until the flame is ignited. (Do not adjust preheat oxygen valve. It must remain fully open at all times.)

Step 5

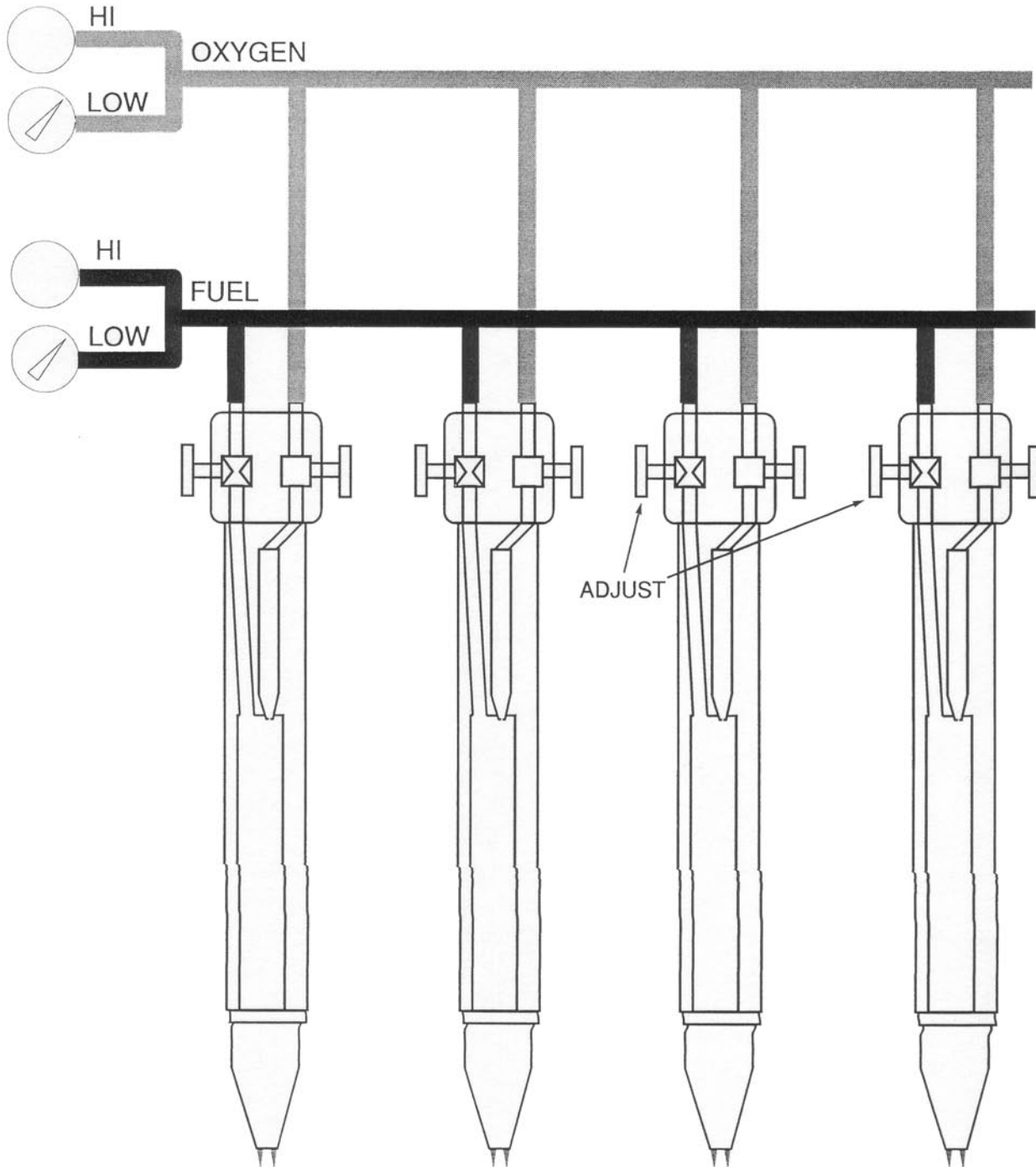


5. Using only the fuel gas valve and low pressure preheat oxygen regulator, adjust the flame for the desired intensity and appearance.



6. When satisfied, let the first torch continue to burn while opening the second torch's fuel gas valve and light its flame. Adjust it using only the fuel gas valve until its appearance looks like the first torch.

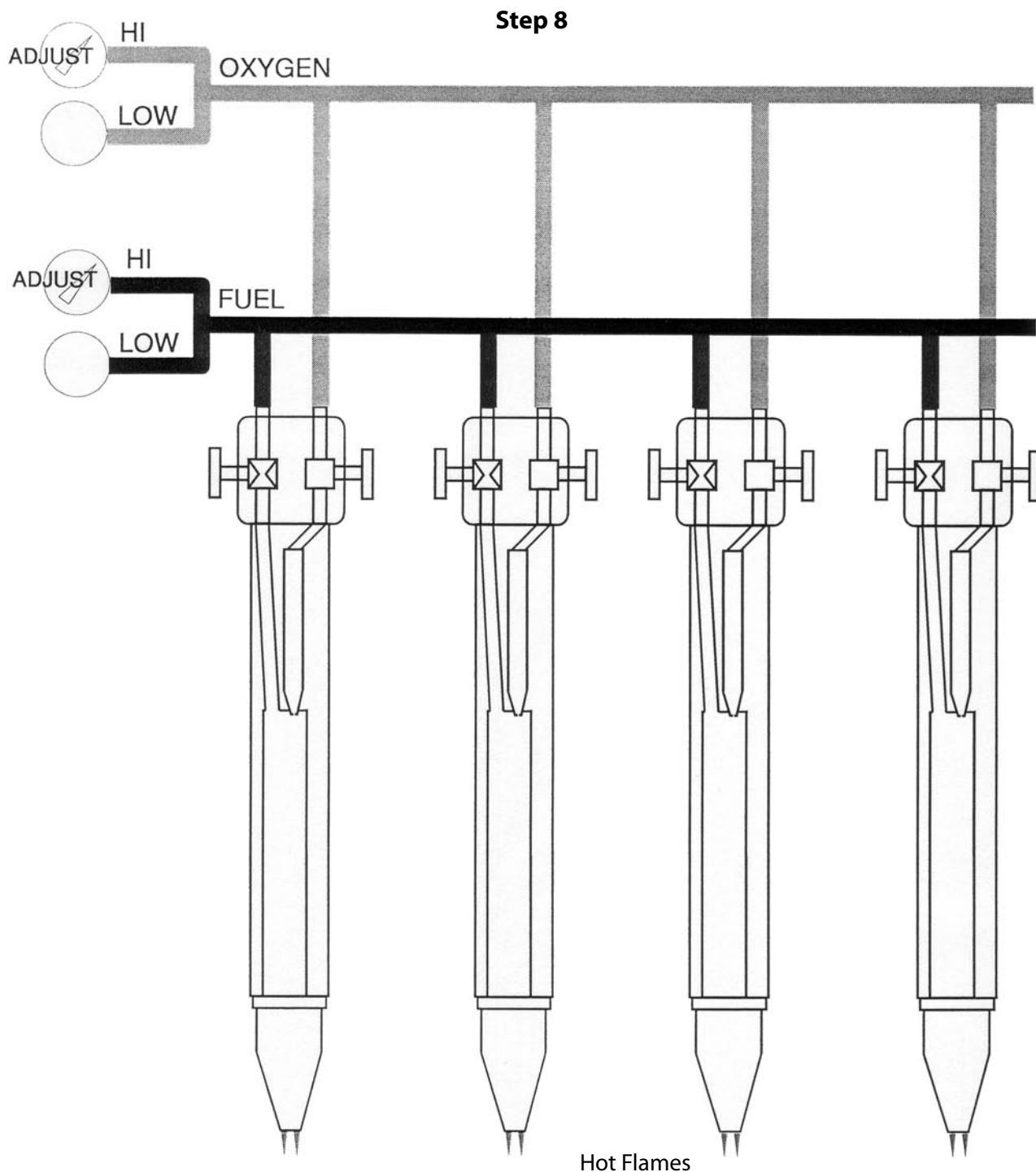
Step 7



Good
Flames

7. While these torches continue to burn, repeat Step 6 on each of the remaining torches (one at a time) until all torches are lit and adjusted uniformly. Some readjustments of fuel gas valves may be necessary when using large numbers of torches to get all flames looking alike. Only Use Fuel Gas Valves! On three regulator systems, the adjustments are complete.

If lighter or heavier preheat is required, it is achieved by adjusting only the fuel and preheat oxygen regulators. Torch valves should only be touched when going through the balancing procedure again.



8. Five regulator preheat systems provide two levels of preheat intensity. High settings are used for intense flames for fast preheat times when piercing. Low settings are used for soft flames during cutting to prevent overheating of the plate edge and burning of the metal with resultant poor cut quality. The machine control will automatically switch between high and low settings for piercing and cutting.

On five regulator systems, continue on with the next adjustment phase. Extinguish all flames and actuate the high pressure regulators. Adjust them to the same pressure settings as the low pressure regulators. Now light all torches and without touching the torch valves, adjust the high preheat oxygen and fuel gas regulators until a more intense preheat is achieved for piercing.

OXWELD®/PUROX® Cutting Nozzle Cleaning Procedures

Important!

To maximize nozzle life, clean them as infrequently as necessary to maintain proper performance. Never clean a nozzle that is performing satisfactory. Although each cleaning creates very little wear on the nozzle, over the course of many cleanings, the cumulative effect can become noticeable.

Identifying Cutting Nozzle Types

Cutting nozzles are grouped by type according to:

<u>Type of Fuel Gas</u>	
<u>Acetylene</u>	<u>Other Fuels</u> Natural Gas/Propane Base Propylene base MAPP Etc.
<u>One-Piece/Two-Piece</u>	
<u>One-Piece</u> Acetylene All Fuel Gases(Never Acetylene)	<u>Two-Piece</u> All Fuel Gases
<u>Cutting Oxygen Orifice Design</u>	
<u>Cylindrical Orifice</u> Acetylene All Fuel Gases	<u>High-Speed (HS) (Divergent Orifice)</u> Acetylene All Fuel Gases

Nozzle Cleaning Tools and Procedures

Cleaning Tools

Cylindrical Bore Kit - Part No. 751F00

High-Speed Kit - Part No. 755F00

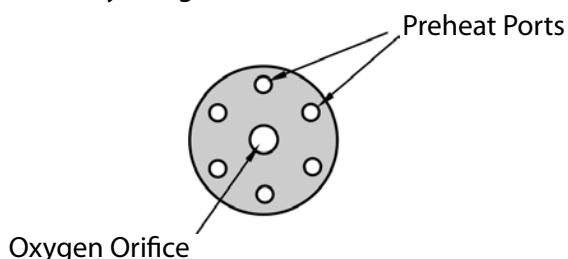
The Cylindrical Bore Kit (P/N 751F00) consists of a series of straight wires of various diameters each with circular ridges around them. These ridges can act as files and can remove copper or brass from the nozzle ports if they are used in an abrasive manner. This kit also includes a small flat file.

The High-Speed Kit (P/N 755F00) consists of a series of straight, smooth wires of various diameters. These have no ridges. The kit also includes a large diameter and a small diameter tapered cleaning tool and a small flat file. Simple cleaning instructions are included inside the cover of this kit. To avoid any mistake, the kit is labeled "High Speed Nozzle Cleaners".

Cleaning Preheats

One-Piece Nozzles

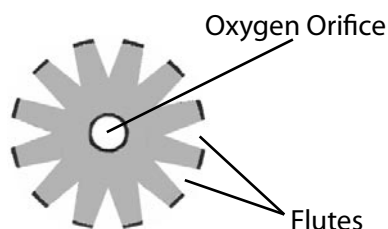
Either kit can be used to clean circular preheat ports. This is accomplished by inserting the appropriate size wire into each preheat port and rubbing it gently against the port walls to dislodge any foreign debris that may have accumulated. Care must be taken, if using the ridged wires, not to apply excessive side pressure or the ridges will remove metal from the port and cause the preheat hole to become distorted. This possibility is prevented by using the smooth wires.



Appendix Figure 1: One-Piece Nozzle, End View

Two-Piece Internals

Two-piece internals have preheat flutes (grooves) which cannot be cleaned using wires. The best tool to clean these flutes is a Brass Bristle Brush (P/N 750F99). Brass bristles are important so as not to remove metal when brushing. Steel is not recommended.



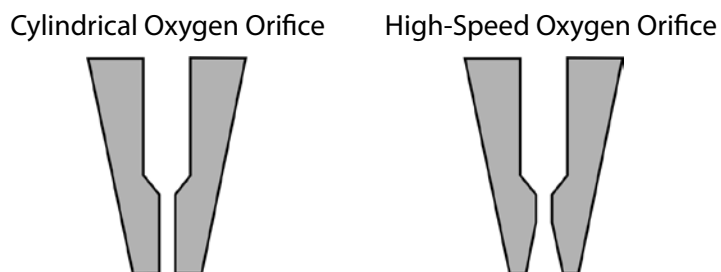
Appendix Figure 2: Two-Piece Internal, End View

Cleaning Cutting Oxygen Orifices

The method used to clean a cutting oxygen orifice is not dependent upon the fuel gas for which it is used or whether it is of one-piece or two-piece design. It is only determined by whether the nozzle has a cylindrical or a high-speed oxygen orifice. This can be easily determined when using ESAB Cutting Nozzles. All PUROX[®] Nozzles are of cylindrical orifice design. OXWELD[®] High-Speed Nozzles are identified by "HS" (high-speed) which is stamped on the outside surface of one-piece nozzles and on the barrel of the two-piece internal. All other OXWELD[®] Nozzles are of cylindrical or special purpose design.

There are very significant differences between cylindrical and high-speed orifices and if the operator does not know which type he is cleaning, he can permanently alter the internal geometry of the orifice and reduce or destroy its performance altogether. Once damaged the nozzle should be discarded since it can seldom be restored to satisfactory operation again.

The following are sectional views of the cutting orifice geometries which have been purposely exaggerated to show the differences which exist between cylindrical and high-speed designs.



Appendix Figure 3: Orifice Design

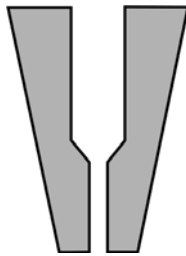
Cylindrical Orifices

Design

Notice that the cylindrical design includes a large entry chamber which feeds the oxygen into a smaller cylindrical passage (throat) that determines the flow of oxygen to the cutting operation as a function of operating pressure at the torch.

For information purposes the laws of compressible fluid flow state that the absolute pressure downstream of the throat (where it exits to the atmosphere) will be approximately one-half the absolute pressure upstream in the entry chamber. For example, if a cylindrical nozzle is designed to operate best at 40 psi (gauge pressure), it is equivalent to 55 psia (absolute pressure) since atmospheric pressure is approximately 15 psi. The discharge pressure would therefore be 27.5 psia (absolute) or by subtracting the 15 psi for atmosphere, 12.5 psi on the gauge. The velocity of the gas stream as it leaves the end of the throat and penetrates the atmosphere is the speed of sound (approximately 1000 ft/sec). With this type of cylindrical design the stream velocity cannot be any faster, because of the laws of compressible fluid flow.

Contrary to common belief, increasing operating pressure does not increase the velocity of the stream. As pointed out above, however, it does increase the exit pressure of the stream by the one-half absolute pressure rule. This increased pressure will cause the stream to expand in diameter as it leaves the nozzle and create a wider kerf resulting in the removal (oxidation) of greater quantities of steel. This generally reduces the efficiency of the cutting operation.



Appendix Figure 4: Cylindrical Oxygen Orifice

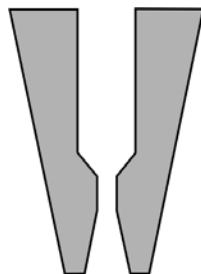
Cleaning

Cylindrical orifices are cleaned by carefully inserting the appropriate size cleaning wire (smooth preferred) into the orifice and rubbing it up and down on the inside surface of the orifice while applying slight side pressure making sure it scrubs the complete 360 degree surface.

High-Speed Orifices

Design

There are similarities between the high-speed and cylindrical orifice designs. Both have large approach chambers which feed oxygen into a cylindrical throat where the flow of oxygen is controlled. In contrast to the cylindrical orifice design, however, the high-speed design includes a tapered expansion chamber between the throat and the exit. This expansion serves two functions -- it reduces the pressure of the stream before it exits to the atmosphere and it provides increased velocity for more efficient cutting operation.



Appendix Figure 5: High-Speed Oxygen Bore

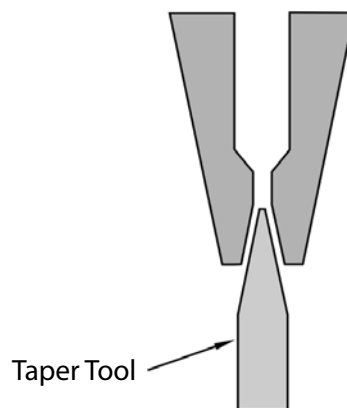
Like the cylindrical orifice design, the pressure of the stream as it passes through the throat is reduced to one-half the absolute inlet pressure. Forty psig inlet pressure would result in an outlet pressure at the throat exit of 12.5 psig. However, the tapered expansion creates additional changes in the stream. As the gas travels through the expansion, the stream diameter increases as the diameter of the taper increases. This reduces the pressure of the stream and simultaneously increases the velocity to levels which can be considerably higher than the speed of sound.

Factors in the expansion chamber which determine the reduction in stream pressure and the increase in velocity are the area ratio of exit to throat and the included angle of the taper. The relationship between the throat and the exit diameter is extremely critical as is the angle of the taper and the concentricity of the expansion. To illustrate just how critical the dimensions are, throat tolerances on OXWELD® high-speed nozzles are specified as +0.0003" -0.0007", exit diameters of the expansion chamber are ± 0.001 " and the concentricity of the two diameters is 0.007" TIR. *OXWELD® high-speed nozzles are precision pieces of equipment and must be treated with care when cleaning to avoid altering any of these dimensions or performance will suffer accordingly.*

Why use high-speed designs?

1. It permits the design of a nozzle whose exit pressure can be tailored closely to atmospheric pressure, thereby creating the least disturbance as the stream penetrates the atmosphere.
2. Nozzles can be designed to operate at considerably higher pressures without the disadvantages of high exit pressures which result in inefficient broadening of the stream thereby creating unnecessary wide kerfs.
3. Operators can take advantage of the higher exit velocity that can be achieved and use it to efficiently blow slag from the kerf and achieve faster cutting speeds.
4. By using higher inlet pressures, operators can use smaller throat diameters to achieve the same volume of oxygen. However, this oxygen is more concentrated since it is at higher pressure. The expansion chamber then permits us to increase the velocity of the oxygen for greater efficiency. The end result is a narrower kerf and 10-15% faster speed that can be achieved with an equivalent cylindrical orifice.

High-speed nozzles can be designed to operate at any desired inlet pressure with virtually any exit pressure by carefully controlling the throat and exit diameters and the expansion angle between them.



Appendix Figure 6: High-Speed Oxygen Orifice

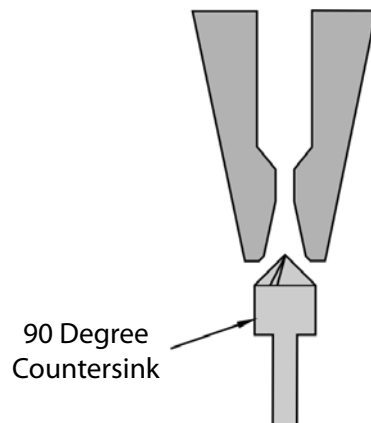
Cleaning

Because of their unique design, high-speed orifices cannot be cleaned in the same fashion as their cylindrical counterparts. The operator must be made aware of the differences in geometry and cleaning procedures to prevent him from accidentally destroying the high-speed orifice. If ignorant of the differences, the operator may force a cleaning wire, which will fit into the expansion exit but may be too large to fit in the throat, thinking that there is an obstruction inside since the wire will only partially penetrate. This may destroy the expansion taper. Operators have been known to completely file away the inside geometry of high speed nozzles with ridged cleaning wires believing they were cleaning the nozzles when, in fact, they were destroying them beyond repair.

Following the brief instructions inside the OXWELD® cleaning kit (P/N 755F00), the operator is instructed to insert the appropriate tapered tool (small for nozzles up to no. 2, large for nozzles above no.2) into the expansion chamber with slight inward pressure. The tool should then be rotated until it turns smoothly. After removing the tapered tool, the largest wire that will comfortably fit completely through both the expansion taper and the throat should be slid in and out of the orifice several times to remove any debris. This will generally return the performance to expected levels.

NOTE: If the proper cleaning kit can not be located for the expansion chamber, a simple round wooden toothpick can be used as a cleaning tool without damaging the nozzle.

In the event that the nozzle does not perform as expected, one final operation that will usually improve performance is a very light 90 degree included angle chamfer at the exit of the expansion chamber. This can be performed using a 90 degree countersink which is commercially available at your local hardware store. The recommended tool is a 1/4" or 3/8" single or three flute cutter. If using the cutter, hold hand against the exit of the expansion chamber and rotate gently to provide the slightest chamfer. This will remove any remaining burrs, slag, etc. and provide a smooth transition between the expansion chamber and the face of the nozzle.



Appendix Figure 7: Chamfer Cleaning Cylindrical and High-Speed Orifices

Cutting nozzles are precision pieces of equipment and if treated accordingly, they will provide months of satisfactory operation. Treat them as you would any other expensive tool and consider the value of the product that they will produce if maintained in good working order. If treated poorly they will not only cost the value of their own replacement, but the cost of scrap and repair of undesirable product that they will produce.

Revision History

06 / 2006 - Re-released under new manual number (was GAS-1129)

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