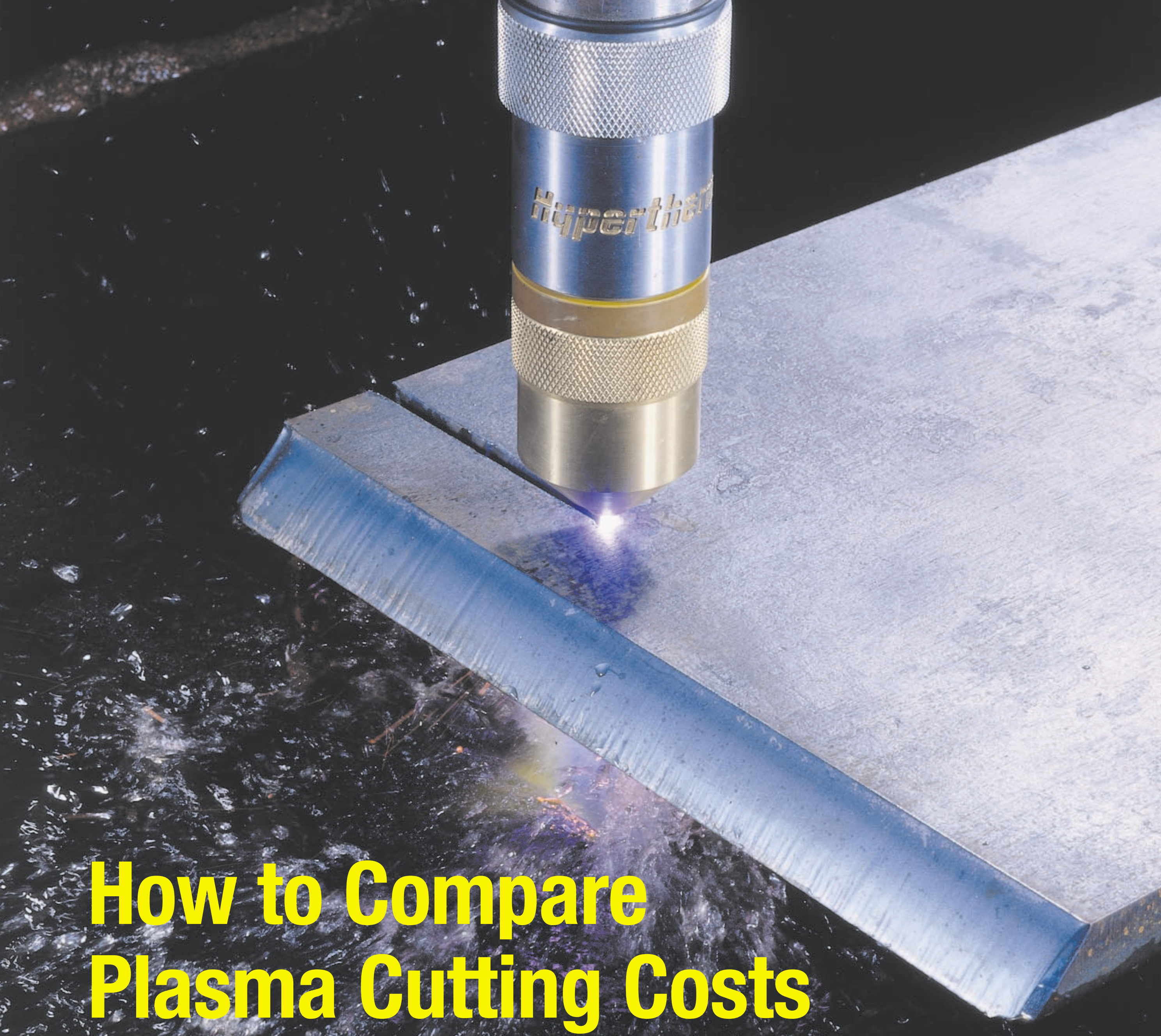

How to Compare Plasma Cutting Costs

Don't neglect the cost savings possible by eliminating secondary operations when choosing between hot-process cutting methods.

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While some fabrication companies process only nonferrous or alloy materials, 95% of all metal cut is carbon steel. Ninety-percent of the carbon steel is less than 1″ (25 mm) thick. Methods for cutting carbon steel vary from shearing thinner materials to oxy-fuel cutting heavier materials. In between, other processes use saws, nibblers, punch presses, EDM, waterjet abrasives, lasers and, plasma-arc cutters (Figure 1).

Choosing a process is very confusing unless there is a clear understanding of the desired end-cut quality and intermediate process requirements. When analyzing cutting costs, keep in mind secondary operations that may be required to prepare the cut part for the next operation or for finishing.

Since most fabrication requirements focus on production rates (how much material can be cut in a given time) and secondary operations (preparing the cut edge for welding, forming, or machining), this analysis will focus on cost differences between plasma cutting processes, with a quick look at others (Figure 2).

To understand operating costs, you must first understand the elements that contribute to these costs. It is easy to look only at the cost of operation and declare a process too expensive. But when total cost per part is compared, increase in cutting speeds

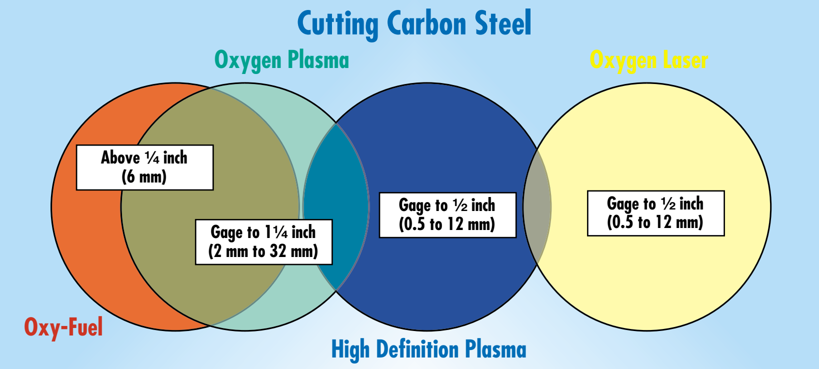
MECHANICAL
Nibbler
Saw
Punch Press
Shear

EROSION
Waterjet

CHEMICAL
Oxy-Fuel

THERMAL
Laser
Plasma
EDM

Figure 1. Methods of cutting carbon steel



Oxy-Fuel

Advantages
1. Low capital investment
2. Low operating cost
3. Good cut edge quality
4. Thick material capability

Disadvantages
1. Slow cutting speeds
2. Preheat time
3. Large heat effective zone
4. Plate warpage
5. Clean up cost to remove slug

Oxygen Plasma

Advantages
1. Fast cutting speeds
2. Wider operating window for quality cuts
3. Minimal clean up
4. Good cut edge quality
5. No preheat time
6. Small heat effective zone
7. Low cost per foot

Disadvantages
1. High capital investment
2. High operating cost
3. Limited thickness capabilities

High-Definition Plasma

Advantages
1. High quality cuts
2. Higher precision than conventional plasma
3. Lower capital investment than comparable laser
4. Minimal clean up
5. Smaller kerf than conventional plasma
6. Small heat effective zone
7. Low cost per foot

Disadvantages
1. Slower cutting speeds than conventional plasma
2. High operating cost
3. Limited thickness capabilities
4. Requires precision motion control
5. Heat effective zone too wide for intricate cutting

Oxygen Laser

Advantages
1. High quality cuts
2. High precision cut parts
3. Higher speeds than high definition plasma under ⅛ inch
4. Minimal clean up
5. Narrow kerf width
6. Small heat effective zone

Disadvantages
1. Slower cutting speeds above ⅛ inch
2. High capital investment
3. Limited thickness capabilities

Figure 2. Comparison of main cutting methods

and reduction in secondary operations change the picture. A company pays an operator to run one of the cutting processes being considered. The operator is paid X amount of dollars per work hour. In addition, there are additional costs for fringe benefits and the cost of facilities to support the operator. Figure 3 shows the relationship of each component to total operating costs.

During the time the operator is being paid, the company would like to get as much productivity as possible. This translates into the maximum amount of material cut in this time period. Add to this the cost of operating the cutting equipment (gases, electricity, and consumables), and you can get cost per hour and cost per foot of cut. A key factor in this calculation is the actual time the equipment is cutting during this period. Factors, such as repositioning time between cuts, time to unload parts and skeletons, time to load new material, time to change worn consumables, and how many torches or cutting heads are being used, must be considered.

Another factor that dramatically affects plasma cutting costs is the relationship between average cut duration and the number of starts on a set of consumable parts. If cut duration is relatively long (e.g., 60-second average cut cycle) with a modern, long-life technology oxygen plasma system, expect fewer actual starts from the consumables than if smaller parts (e.g., 20-second average cut duration) are being made.

If you consider only the total cutting cost per hour between oxy-fuel and nitrogen plasma, the oxy-fuel process is the least expensive to operate, followed by nitrogen plasma-arc cutting (Table 1). Consumable life (nozzles and electrodes) is very good with these processes. Using oxy-fuel, however, time to preheat the metal before piercing, time to clean the tips to get good consumable life, and slow cutting speeds make it less favorable when cutting material thinner than 1″ (25 mm). Nitrogen plasma-arc cutting will produce cutting speeds three to six times faster than oxy-fuel, but at a higher operating cost. But with the additional material throughput, the actual cost per foot of cut is much lower than with oxy-fuel.

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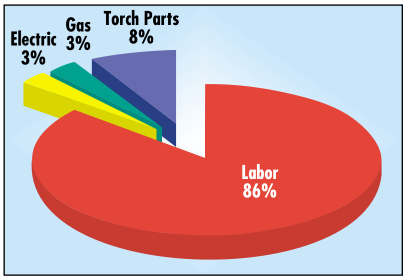

Figure 3. Operating cost components

Table 1. Cost Comparison, $/ft				
Sheet Thickness, in. (carbon steel)	1/4	1/2	3/4	1
Oxy-fuel, 3-torch system				
Cutting speed, ipm	60	48	42	36
Cost per ft, $/ft	0.19	0.25	0.30	0.37
400A Nitrogen Plasma				
Cutting speed, ipm	150	115	75	60
Cost per ft, $/ft	0.18	0.25	0.38	0.49
400A Oxygen Plasma				
Cutting speed, ipm	190	160	95	70
Cost per ft, $/ft	0.12	0.15	0.26	0.35

Nitrogen plasma's downfall is that carbon steel thicker than ⅜″ (10 mm) has a good chance of having dross (slag) buildup that will have to be removed. The cut edge will also be hardened by the cutting process and will have to be removed by grinding before it can be machined or formed. If the part is to be welded afterward, the edge has to be processed to remove nitrides that cause weld porosity. With thicker materials, the top part of the cut edge will be rounded and may have to be squared by an additional process.

Oxygen plasma cutting produces a high quality cut edge, metallurgically similar to the oxy-fuel process. A secondary benefit is the large operating window that can be defined in terms of dross-free interval and at the cut speed that an oxygen plasma system can deliver and still produce a quality cut.

"Dross-free interval" is defined as the cutting speed range in which virtually no dross is produced on a given material thickness and at a given power level. This dross-free interval generally starts as speed is increased to the point low-speed dross (heavy, easy to remove) is eliminated and ends as speed increases to the point that high-speed dross (light, yet hard to remove dross) forms. This speed range is the dross-free interval. Many newer plasma systems are specifically designed with very wide dross-free intervals to provide more consistent quality.

As shown in Table 1, when comparing strictly operating costs to arrive at a cost per foot value, oxygen plasma, while less expensive to operate, does not appear to offer huge cost savings over nitrogen plasma.

If, however, you consider the cutting operation's total costs over a year, the oxygen plasma system comes out ahead. Tables 2 and 3 show the differences in cost between a nitrogen system and a modern, high-powered (400 amp) oxygen system equipped with long consumable life technology over the course of a year. Both systems are assumed to be cutting the same part, two shifts a day. While consumable costs (nozzles, electrodes, gas, and electricity) are much higher with oxygen

Table 2. Consumables Cost of Nitrogen Plasma vs Oxygen Plasma (one year)		
	Nitrogen Plasma	Oxygen Plasma
	400A	400A
Type of Material: 1/2''-thick carbon steel		
Size of pieces cut: 12'' diameter		
Length of cut per piece, in.	37.7	37.7
Time to cut each piece, min	0.377	0.236
Time to reposition and pierce next cut, min	0.17	0.17
Number of pieces from 4' x 8' plate	21	21
Time to cut one plate, min	11.42	8.45
Time to unload and load plate, min	15	15
Electrode life, hrs	4	1
Time to change parts, min	15	5
Pieces cut per electrode	637	241
Plates per electrode	30	11
Plates per shift	17.84	20.1
Electrode changes per shift	0.59	1.75
Shifts per day	2	2
Production shifts per year	480	480
Parts produced per year	179,787	202,577
Cutting hours per year	1130	796
Total parts used per year:		
Electrodes	282	841
Nozzles	226	841
Swirl rings	14	10
Retaining caps	4	2
Total parts cost per year, $		
Electrodes	5902.49	19,774.08
Nozzles	5196.45	30,292.20
Swirl rings	347.37	193.91
Retaining caps	209.69	459.92
Total cutting cost for year	11,656.00	50,720.11
Consumable savings with 400A Oxygen		-$39,064.00

Table 3. Operating Cost of Nitrogen Plasma vs Oxygen Plasma (one year)		
	Nitrogen Plasma	Oxygen Plasma
	400A	400A
Type of Material: 1/2''-thick carbon steel		
Total nitrogen used per year, cubic feet	186,394	168,483
Total oxygen used per year, cubic feet	0	114,111
Total cost of nitrogen used per year	$18,639.44	$16,849.31
Total cost of oxygen used per year	0	$4,564.43
Total power used per year, kWhr	$49,323.25	$46,141.10
Total power cost per year	$2,959.39	$2,768.47
Total gas and power cost per year	$21,598.84	$24,182.21
Power and gas savings with 400A oxygen		-$2,583.37
Total Savings		-$41,647.48
Labor rate, $/hr	17.45	17.45
Total hours worked per year	3840	3840
Total labor cost per year	$67,008.00	$67,008.00
Cost per foot of cut	$0.18	$0.22
Cost of grinder to remove slag:		
Labor/overhead rate, $/hr	$17.45	$17.45
Total hours worked per year	3840	480
Total labor cost per year	$67,008.00	$8,376.00
Total Cost per foot of cut	$0.30	$0.22
Total Cost Savings using Oxygen Plasma		**$16,985.00**

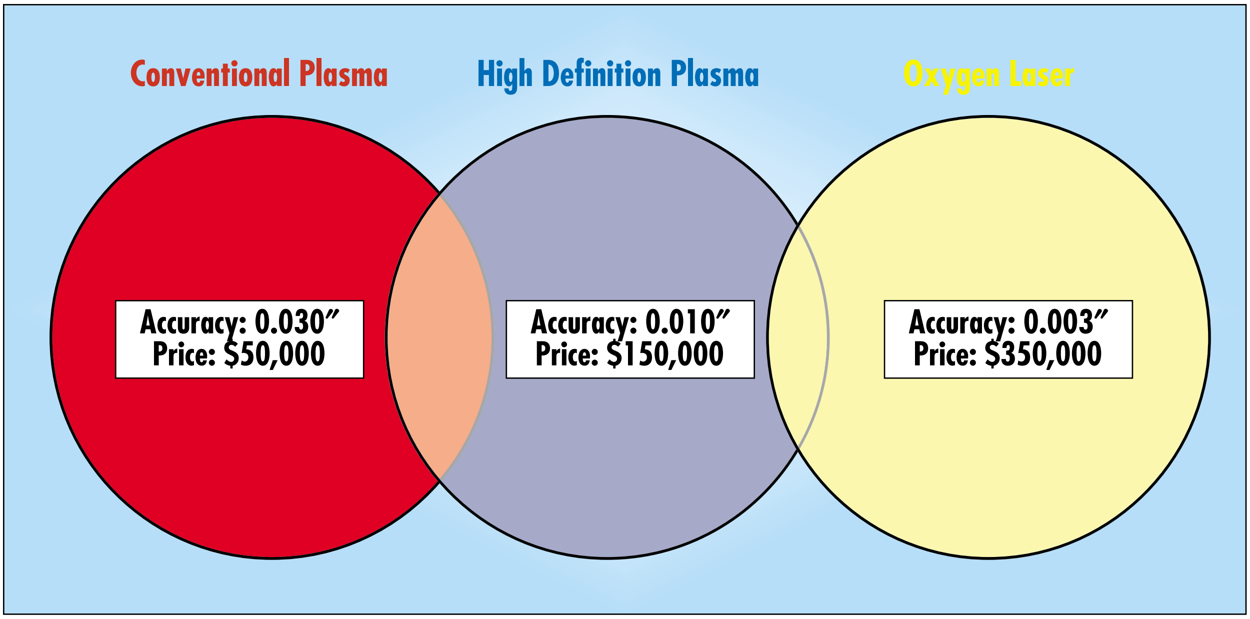

Figure 4. Performance comparison of cutting methods

plasma, cutting speeds are also substantially higher (Table 2). But when the secondary costs of grinding nitrogen plasma costs to remove hardened edges and dross and edge squaring are added (Table 3), there are substantial savings per part with the oxygen system.

When precision beyond the ±0.035″ (0.9 mm) norm for conventional plasma systems is required, laser machines (±0.003″, 0.08 mm)) are the dominant choice. With the introduction of high-definition plasma systems, an alternative to laser cutting in the middle ground of this tolerance range (±0.010″, 0.3 mm) is now provided (Figure 4).

Doing a cost comparison between the two processes is difficult because of differences in consumable life and how that is presented in the cost of operation. It is easy to compare laser system gas and electrical costs. But since the consumable lens is replaced after a few months with substantial down time, it is hard to pin down a cost.

It is important to consider all aspects when comparing systems to obtain a true cost per foot of cut or per part. What may appear on the surface to be an expensive process may prove to be a better value when secondary operations are included. ❒