

Perfecting By Gary Sheriff

ALUMAMark®

Laser Markable Aluminum



Lasering Techniques

If you own a CO₂ laser or are thinking about purchasing one, you may have heard of a laserable aluminum material called AlumaMark from Horizons Incorporated, Cleveland, OH. This specially coated, laser beam-sensitive metal is designed especially for CO₂ laser marking. AlumaMark represents a major technological advance because it eliminates all of the extra steps associated with marking bare metal using a laser fusible coating such as Cermark.

If you are a CO₂ laser user, this article will help you to achieve the best possible results not only with AlumaMark, but also with other laserable products. We'll take an in-depth look at what's happening when the laser light hits the material surface for a better understanding of how to achieve optimum laser marking. If you're still contemplating a laser purchase, the information in this article will help you formulate a list of questions to ask the laser vendors so you'll be able to choose the best laser for your needs—especially for those of you wishing to achieve laser-perfect results.

First, let's look at why there's a need for AlumaMark. Typically, the light energy from a CO₂ laser bounces off bare metals, causing no mark and no cutting action. However, if enough "brute force" (CO₂ laser energy and heat) is delivered to a metal that contains carbon, such as steel, a reaction does take place creating a contrasting color mark. But using this much power in an attempt to mark metal does involve tradeoffs and the possibility exists that you could damage your

power supply or warp the material you're working with. In other metals that don't contain carbon, such as aluminum, no reaction takes place when a CO₂ laser beam strikes it.

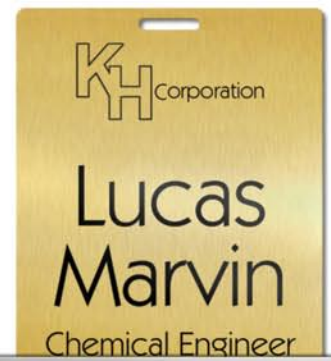
There's one other issue with aluminum—it becomes a "heat sink" (a material which readily absorbs and dissipates the heat). For example, if you held the flame from a cigarette lighter close to similar sized pieces of steel and aluminum, the steel would become extremely hot, whereas the aluminum would only feel lukewarm in the same time frame due to how it dissipates heat.

Let's quickly change gears and compare the CO₂ lasers that most of you are using with other types of lasers that are used to mark metals. You may have heard of YAG, Vanadate and fiber lasers—these three lasers produce a different wavelength of laser energy from CO₂ lasers but their wavelengths are similar to each other and therefore they provide similar metal marking results no matter which of the three you use.

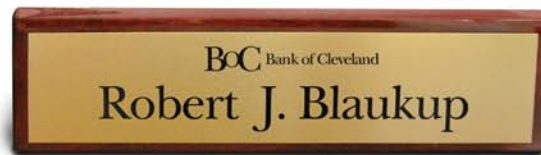
CO₂ lasers are very different. YAG lasers are generally more expensive and are used to mark different mate-

rials compared to a CO₂. This is especially true of metals. If you take the same piece of steel and aluminum from the previous example, the energy of the YAG laser would quickly be absorbed (as opposed to reflected, as with the CO₂) into the steel thus creating a very visible black mark in a matter of seconds due to a laser-induced chemical reaction with the carbon in the steel. The metal is still heated, but not as much as if a CO₂ laser had been used. We already know that aluminum doesn't contain carbon, so the best that a YAG laser can do on aluminum is create a frosted mark by slightly penetrating the aluminum's surface.

Now let's again consider AlumaMark. This is a material that allows the user to directly create black marks on aluminum with a CO₂ laser. The contrast happens at the surface, which means you wouldn't be able to feel the mark by scraping the surface with your fingernail. This process is not to be confused with the mark that occurs when a laser-fusible emulsion like CerMark or TherMark is applied to a metal and then bonds to the metal during the lasering process. Instead, AlumaMark is an aluminum material



GI TWO PHASE INDUCTION MOTOR					
SERIES 4 POLE		TYPE 3A		FRAME 3A	
Hz	86.0	ROTOR	12	RATING	10
V	12.0	TH. CLASS	316A		
A	14.0	AMB TEMP	92 °C		
r/min	3200	TEMP RISE LIMIT	42 K		
CODE	14RW				
RULE	78 POSI 345				
SERIAL			FLSO3904-23		
DATE			2.14.2003		
Global Industries			CLEVELAND, OHIO 992192-61		
MASS			363 kg		
BEARING		DE		12	
NDE		11			



AlumaMark samples courtesy of Horizons Inc., Cleveland, OH.

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that is pre-treated by the manufacturer with a proprietary coating that absorbs CO₂ laser energy. The resulting mark (properly applied) is black and best of all, a secondary process, such as adding emulsion, is not required.

AlumaMark is used in many industries for creating products such as signs, awards, nameplates, trophy plates and bar code labels. When proper lasering techniques are followed, excellent quality images, logos, text, and bar codes are produced on the AlumaMark surface.

AlumaMark can be frustrating for a first-time user to work with due to the material's sensitivity and the variability of individual laser systems. AlumaMark has a relatively narrow "exposure latitude." This means that it will provide a beautiful, contrasting mark when correctly exposed to the laser beam, but over- or under-exposure can result in a less-than-perfect mark. The key to achieving gorgeous black marks in AlumaMark is understanding your laser and fine tuning all of the lasering variables.

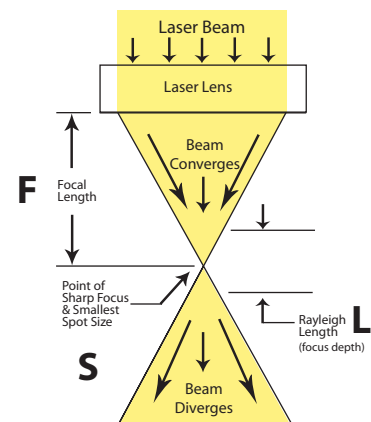
It's helpful to first understand a little about the laser rather than spending a lot of time in hopes of finding the best machine settings by trial and error. The manufacturer of AlumaMark, Horizons, provides suggested settings for different laser systems, which vary by laser manufacturer and model. The information given in the hints is a good place to start, but for best results, you need to fine-tune the recommended settings for your own laser.

The first reason for this is that during the laser tube manufacturing process the tube is filled with a CO₂ gas mixture. This process is an imperfect science. For instance, a 45 watt laser system is guaranteed to deliver at least 45 watts of power. Actual power can be and probably is higher, but it's still rated as a 45 watt laser. In essence, two "identical" laser tubes can vary in power output by 10 watts or more. Since every laser is somewhat different from any other laser, marking results will differ slightly, especially when you're working with AlumaMark.

I mentioned earlier that achieving great results on AlumaMark is possible, but these results may come only after some trial and error cycles relative to your specific laser. For exam-

FOCAL LENGTH F	SPOT SIZE S	RAYLEIGH LENGTH L
1.5"	.004"	.070"
2.0"	.006"	.120"
2.5"	.007"	.180"
4.0"	.012"	.240"

This shows the effect of using laser lenses of different focal lengths. The greater the focal length, the larger the spot size and the greater the Raleigh length (depth of field).



ple, simply changing the power setting by 1% or 2% can give you very different results; this can change the mark from light brown to black.

Now that you have an idea about the sensitivity and precision needed for the process, let's focus on the laser system and its mechanics. There are several types of CO₂ laser systems, but we'll focus on the popular "flying optics" design used in most of the CO₂ lasers within the recognition and identification industry.

A laser engraving system generally has several mirrors and a lens to focus the laser energy down to a small spot. For example, think of using a magnifying glass to focus the sun to burn a piece of paper on the ground. If the size of the magnifying glass lens changes, the focus distance (point of focus) changes. This also affects the heat intensity. With a larger lens, you need to hold the magnifying glass farther away from the paper to focus the beam and it may take a little longer to burn the paper, but when the paper starts to burn, the burn area will be large due to its larger spot size. If a smaller lens is used, then the "point of focus" distance between the magnifying glass and the piece of paper is closer and the paper burns faster although the area that burns will be a smaller spot compared to the larger lens.

Switching back to lasering, CO₂ lasers use lenses to focus the CO₂ energy. Typical lens sizes (focal lengths) include 1.5", 2", 2.5" and 4". Each lens focuses the laser beam to a predetermined diameter spot and each lens has a unique focal distance.

Choosing the right lens for your

job is important. The 2" lens is a great place to start and is typically the standard lens you receive when you purchase a laser. A short focal length lens, such as a 2" lens, is the best choice to achieve the strongest intensity and best resolution, while larger lenses have a larger spot size and a better depth of focus. So, what's the tradeoff and what lens should you use, especially for AlumaMark?

First, let's use another analogy—consider the beam to be shaped like the letter "X" as it projects downward from the lens (Fig. 1). As the beam leaves the lens, it is large but it begins converging toward the center of the X, where the beam is both the smallest in diameter and the most intense, energy wise. Just below this center point, the beam starts to diverge again into a larger diameter with less intensity. Marking will cease after some distance. This is very apparent on a round or a curved item, for example. A smaller lens means that the center of the X is very small, therefore, even a slight movement above or below the center of the X creates a rapid drop off in the laser energy levels. A longer focal length lens, on the other hand, will stay better focused when you make the same focusing adjustment.

If your artwork has small intricate designs or small text such as four point text (.055" character height), you may want to consider a 1.5" or a 2" lens. Let's consider that the spot size from the 1.5" lens is about .004" in diameter, whereas the spot size from a 2" lens is about .006" in diameter. As a rule of thumb, text should be marked using at least 10 vertical pixels to get clear, sharp results. If you multiply the

.004" (spot size) x 10 (pixels) = .040", this means that the 1.5" lens will mark four point text very well. Using a 2" lens you would multiply .006" x 10 = .060". This will probably be satisfactory, but the characters won't be quite as sharp as those marked using a 1.5" lens. If you use a 2.5" lens, with its .007" spot size, characters, .040" high will look blurry. It's necessary to mention that spot size also varies depending on variables such as quality of beam, beam collimation, speed, power and material.

It's apparent that a smaller lens will give you the clearest and sharpest results, but now let's consider the tradeoff—depth of focus. Imagine that the center of the X becomes smaller as the lens size decreases. If your item is curved, the beam will go out of focus as you move the lens farther away from the high or low point on the curve. This is a big reason why you need to use a larger lens if you're marking on a non-flat surface such as a tapered, domed or cylindrical item. For marking beyond focus range, such as around a circumference, it's best to use a cylindrical attachment rather than moving the lens too far out onto the curvature.

The focus depth, also called Rayleigh length, is the vertical distance spanning from just above the center of the X to just below center where you will generally achieve a satisfactory laser cut. This distance changes for each different size of lens, as previously described. For example, a 1.5" lens has a Rayleigh length of about .070", a 2" is about .120" and a 2.5" lens is about .180". The larger the focal length of the lens, the better the quality of the mark when you're marking on concave and convex surfaces where the focus changes due to the curve.

There is one other factor that can create possible exposure problems with AlumaMark (or any material with a critical exposure range). If you own a flatbed laser system and have tried to use your entire table to mark on any material, you may have experienced different engraving results from one end or corner of your table to the other. For example, let's say you focus on the upper left corner of your item and start the laser. At the end of the process the mark on the right

side of the item isn't as sharp, dark, or deep as the mark on the left side of the item. You also may notice differences in the cut between the top and bottom of the table. Focus is usually the culprit that causes this difference. Either the item isn't laying flat on the table or perhaps the laser table isn't flat relative to the laser head as it travels across the entire surface of the material. A quick check can easily be performed by manually focusing on the left portion of the material on the laser table and then moving the laser head to the right side of the table and confirming that the focus is still just at the bottom of your manual focus tool. This focus tool check should be repeated near all four corners of your laser table.

If you find that your laser table isn't flat, you may need to contact your laser supplier or simply use only the part of the table that passes the focus test. Note, too, that other factors such as laser beam divergence can affect the quality of the mark, especially when you engrave at opposite corners of the table.

AlumaMark is a thin material and tends to bow and therefore may not lay flat on the laser table. It's important to first take all necessary measures to keep your material flat by using paperweights, tape or magnets (some laser systems have a magnetic steel table) to hold your material flat against the table.

Now that you have the engraving area selected and you're sure your material is flat, you can fine-tune your laser variables. The main variables are laser power, raster speed and ppi (pulses per inch), if available. (I'll explain ppi a bit later.) Through experimentation, I've learned that AlumaMark works best with a specific amount of average power delivered at a certain speed. The laser delivers the energy by pulsing the laser as the laser head travels back and forth in the raster motion (similar to an inkjet printer). The trick is trying to simulate the pulses so that they deliver energy as smoothly as a flame from a cigarette lighter and then adjust the speed so that the right amount of heat is delivered to activate AlumaMark's special laser beam-sensitive coating.

For our test, we used a Trotec, 75 watt, Speedy 300 laser system. To

minimize variables, we kept the speed to a constant 20% to allow proper heating of the AlumaMark surface. Please keep in mind that the Trotec laser is rated fast at 140 inches per second and if another type of laser is used, your speed will need to be a calculated on the ratio depending upon the rated speed of your particular laser system. For instance, if your laser system is rated at 100 inches per second, the comparable speed should be 28% to be consistent with the 20% speed of the Trotec laser. We chose a 2" lens, 1000 dpi (dots per inch), 1000 ppi and 20% power for the first test.

Some systems have ppi or pulses per inch as a variable. Pulsing the laser in the raster mode makes the laser system flexible, allowing the marked result to be optimized. In our case, we're using a slow speed at 20% and by maximizing ppi at 1000, we could pulse the laser more often to create the heat effect necessary for the best mark. If your laser system doesn't allow you to change the ppi, you can try decreasing the speed a little more.

At 20% power the AlumaMark was over-lasered. By changing just the power parameter and doing a little experimentation we found the best setting for a really beautiful black mark. In just a few minutes time, we found that the best power setting with our laser was 13%. The results from 12% and 14% power were not as black as we achieved using 13% power. Using logic relative to the way almost all items are marked, it would seem appropriate to increase speed and power to reduce the process time. This is only true to a certain point with AlumaMark. We tried increasing speed to 30% and 40% and increased power to compensate. Although the AlumaMark did mark well, the results were never as black as what we achieved at 20% speed. This convinced me that the dwell time of the laser to react with the AlumaMark coating is very important.

Please note that AlumaMark is available in several different background colors. The color we tested was Satin Gold. Each color of AlumaMark may require slightly different settings for best results. The laser light absorbs differently into each different color pigment. This is similar to heat inside of a car in the middle

of summer. A white car stays cooler because the sun's rays bounce off the white whereas a black car gets warmer because the black absorbs the sun's rays.

Now that we have the correct settings for the laser, we can optimize the mark a bit further by setting the machine about .040" out of focus. This can be done by either raising or lowering the laser table that distance. Some laser systems allow the operator to simply enter, using your keyboard, the number .040" to move the table that exact amount. Refocusing to about .040" beyond regular focus acts to dampen the pulsing and create the heat effect we prefer.

By doing this, the resulting mark is more robust, so if you were to change the power to 12% or 14% the mark may look as good as our optimized setting of 13%. Also, the mark may be a little bit blacker when you compare it to the result you achieved when it was in sharp focus.

This is very important when marking a 2D matrix for UID (Unique Identification). UID marking is a new market that has recently become a major factor in the aerospace industry. Matte silver AlumaMark is one of the favorite materials used for making UID nameplates. Once the 2D matrix is marked, it must be read and graded by a verification process. The verification process grades the mark on several criteria including contrast. This is why it's so important to get the blackest mark possible. For more information about the UID nameplate market, take a look at EJ's site www.uidmarkinginfo.com.

Each lens has its own unique properties. Using our 2" lens we found that .040" out of focus is the number that worked best. One other aspect to consider when defocusing your lens is that as you defocus the lens, it starts to simulate a larger focal length lens. In other words, the spot size grows and at some point will be the same size as the next larger size lens. If you think about the shape of the X again, just before and after the point of focus, the beam converges at the center and then starts diverging. At one point, the spot size will be the same as a larger lens. The disadvantage to simulating the larger lens is just that, it's simulated, so the added focal depth of that par-

ticular lens is not a factor if trying to mark on a curved surface. Marking on a flat surface should give a lot of flexibility since focal depth shouldn't be a factor. Further adjustment of the power may be necessary when simulating a different lens.

Perhaps after taking time to get the blackest mark possible and taking all focal precautions, you'll find the result you get still isn't consistent when you compare the middle to the end of the mark. Often you'll find that the mark appears to be lighter on each end and darker in the middle of the item. For instance, if you were marking "12345," the 1 and 5 might be lighter than the 2, 3 and 4. This may be caused by the motor action. The motors in laser systems have an acceleration time (ramp up), a velocity (stead state) and a ramp down time as the laser head travels back and forth. Since AlumaMark is very sensitive, it's possible that the inconsistent effects toward the ends of the mark are caused by this mechanical ramping up and down. This will most definitely affect your UID tags when you're trying to get an excellent grade on your mark. To reduce this effect, you can lower your speed, but this will cost you some process time.

Now let's examine yet another example where very small text is needed and begin by assuming that you have

already achieved the best possible black marks. The job calls for very small text such as four or even three point text. Most likely you would use a 1.5" lens for the best clarity and focus of either "in focus" at a slower speed or slightly "out of focus," to help achieve the blackest mark. Your primary concern is still the clarity of the letters. The spot size is small enough to mark the letters, but the letters are still a bit fuzzy when examined with the naked eye. Under magnification, perhaps with an eye loupe, you might notice that the laser didn't perfectly mark the vertical lines directly under the previous line. Another example is a 1D bar code, such as found in a grocery store or a 2D matrix as used in UID codes. The bars of the 1D bar code aren't exactly straight and the square cells in the 2D code don't make up a perfectly square cell. An imperfect cell in a 2D matrix will grade poorly due to "cell modulation." This is another criteria used in grading the 2D code in addition to contrast. The issue relates to mechanics and electrical delays, but we won't go into too many details about why this happens. The troubleshooting techniques you could use include slowing the process speed on the letters and the 2D codes. For the 1D code, perhaps turning the bar code 90° will

ALUMAMARK EXPOSURE TEST

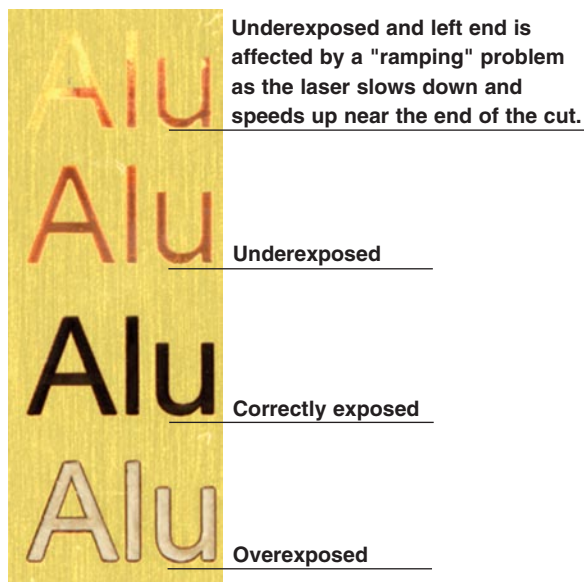


Figure 2

help since the laser will be marking a longer line instead of shooting across the bar code in a series of short bursts. This will increase your process time because the laser must now complete the 1D bar code vertically.


With all of these suggestions, I want to note that some laser systems do a much better job than others of compensating for any mismatched raster lines and they therefore produce very clear lines even at the smallest text sizes. Mismatched raster lines occur when the laser “fires” in a slightly different spot (due to timing issues) when the laser moves left versus when it moves right. This

usually shows up as jaggedness in vertical lines.

Whether using AlumaMark or other products in your CO₂ laser system, you can achieve great results if you take the time to examine the mark and troubleshoot the problem. An eye loupe is always very helpful to see what’s actually happening at the surface level. In the case of AlumaMark, speeds should always be relatively slow and the beam just slightly defocused to induce the necessary heat required to make a nice black mark.

Each laser system has its own unique properties and before you’re ready to mark AlumaMark, you should

test your laser so you can achieve the best possible marks for each different color. Don’t be afraid to experiment to find the machine settings which create the blackest mark. Start with the focus and the flatness of your table and, if speeds are slow enough, you may be able to overcome some hardware issues.

The laser system itself is a big variable and finding the perfect settings will help you achieve the best marks on AlumaMark or any other product for that matter. Be aware that even though laser systems may look similar, some laser systems will work better than others. 

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Notes: