Martin MAC 350 Entour

By: Mike Wood

Figure 1 - Fixture as tested

I've reviewed quite a few LED-based products over the last few years, as we've followed the evolution of entertainment lighting products using them as light sources. The first products in that evolution were floods with very little beam control; they were followed by wash units with optical zoom systems. Today, we get to review our first LED-based spot unit, the Martin MAC 350 Entour. Although it's the first to be reviewed here, it's not the first LED-based spot on the market, but it is definitely one of the first with light levels high enough to make it directly comparable with more conventional automated spot units. The way Martin Professional achieves its high output also makes it unusual in another way: The MAC 350 Entour only uses white LEDs. This means no RGB additive color mixing and thus a reliance on dichroics for color. More about that, and the associated pros and cons, later in the review.

This review follows the normal format; I take a single unit supplied to me by Martin Professional as typical of the product—The MAC 350 Entour has only just been launched, so I was sent one of the very first units straight off the production line—and take measurements of everything I can think of that's measurable, from light source to output. The MAC 350 Entour is fitted with a universal power supply rated from 100-240V 50/60Hz, and, for these tests, the luminaire was run from a nominal 115V 60Hz supply (Figure 1).

Light source and primary optics

The light source makes this product particularly interesting—but, because of its nature, it is also one of the hardest components to evaluate. With a rated life in excess of 60,000 hours (nearly seven years if the unit ran 24/7, or over 20 years running a more realistic eight hours a day), changing a lamp isn't something you should ever have to do. This also means that getting to, and replacing, the light source becomes a service task performed by a maintenance shop rather than something that has to be made easily accessible for the end-user.

The MAC 350 Entour uses seven CBT-90 LEDs from Luminous Devices. These are very high-power LEDs, each rated to handle 50W of power. They are also small, and it is this high power density, along with the heat transmission systems included in their packages, that is making Luminous Devices products more and more common in entertainment lighting products. As I've mentioned before, the key to a long and happy life for your LED emitters is keeping them cool—they'll take everything you can throw at them as long as you keep their temperature controlled. Martin takes those seven packages on their copper and ceramic board—and their 350W of heat—and mounts them directly to a large aluminum heat sink. Figure 2 shows a

Figure 2 - LEDs and lenses

Figure 3 - LED and connections

Figure 4 - Rear fan

view of the layout through the main aperture plate. There is a central LED package with six others surrounding it, and each LED die is capped with a large custom-molded TIR-lens. To give you an idea of scale, each of the large lenses in Figure 2 is about 20mm in diameter. What you can't tell from the photo is that the mounting surface isn't flat; instead, the heat sink is cast as a concave dish. The central LED is mounted normal to the aperture but the surrounding six are all tilted in, angled so that they each point towards the center of the aperture. Figure 3 shows the detail of one of the packages; you can see the lens at the bottom right and the two 0.25" blade power connections off to the left. Looking at the TIR lenses, my assumption is that each images its respective LED die across the whole aperture to form a portion of the overall brightness, not a sector of the image. Although the beam from each one individually probably isn't that smooth, the overlap and averaging of all seven superimposed on top of each other provides an acceptably even coverage across the gate. The development and design of this TIR lens is proprietary to Martin Professional, and, I understand, has been designed in collaboration with a Danish university.

As already mentioned, all the LEDs are white; there are no individual colors. There are a few obvious benefits in doing this. Firstly, white LEDs are currently the most efficient available, with the vast majority of R&D from the large semiconductor manufacturers going into producing better and better white light. The reasons for that R&D focus are clear. Ninety-nine percent of the lighting world only wants white light; only we oddities in the entertainment lighting want colors! High-power white LEDs are commercially available with efficacies of 100 lum/W or better, while white produced by combining red, green, and blue in a typical RGB array might only be capable of half that. Secondly, with only white LEDs there is no need to combine and homogenize all the colors into a single beam, an operation which can easily introduce high losses into the system; everything is already mixed white. Finally, with white LEDs only, there is no need to worry about the different thermal sensitivities of each color and thus no problem with color consistency. The downside is, of course, that Martin cannot use the efficiencies of additive color mixing and, instead, must use inherently inefficient subtractive mixing. When using additive color mixing to make blue light, you just need the blue LEDs; the red and green may be turned off completely. With subtractive mixing and white light at source, all of the unit's LEDs are running all the time and a blue filter produces the blue light. In this case, any red and green light is reflected back by the filter and essentially wasted.

With LEDs, strobe effects are, of course, completely electronic—no moving parts are required. The MAC 350 Entour offers a comprehensive range of strobe options and pattern variants with speeds up to 8.25Hz. This includes a pulsed strobe, where bursts of high-speed 25Hz pulses are themselves strobed at a lower speed.


Figure 5 - LED heat sink


Figure 6 - Lens and wheels


Figure 7 - Front lens

Heat management

The LED heat sink in the MAC 350 Entour is quite complex. The inner surface forms the concave dish already discussed, while the outside is a labyrinth of fins designed to maximize the surface area to conduct that heat away to the surrounding air. With 350W to dissipate, convection cooling is insufficient; there is also a large-diameter fan pushing air through this labyrinth. Figure 4 shows the fan, while Figure 5 shows the heat sink when the fan is removed. In operation, you have a couple of options with the fan; you can either leave it in regular mode where the fan speed is thermostatically controlled, allowing the LEDs to be run at full power, or you can set the fans to "silent" mode, where they are run at much lower and quieter speeds—but the output of the fixture is significantly reduced. In my tests, the output dropped to 55% of full output when in silent mode.

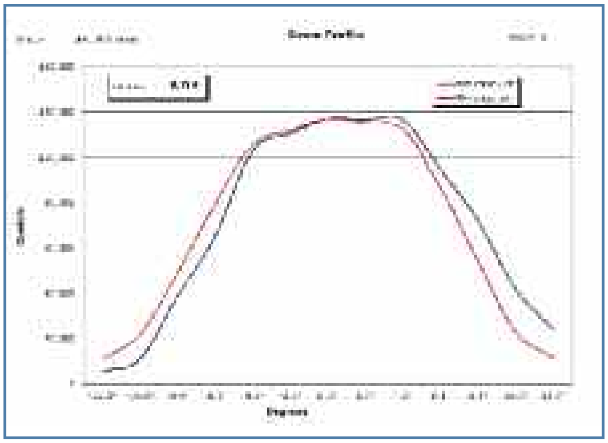
Figure 8 - Output

Optics and output

Actually, we've already pretty much covered the optical system. The single TIR lens on each emitter is really all there is, apart from the output objective lens. The MAC 350 Entour has a fixed beam angle, so that output lens is a single group that is moved backwards and forwards by a worm gear to provide focus control. This worm drive is fairly slow, taking 5.5 seconds for the focus lens to move from one end of its travel to the other. Figure 6 shows the optical module and the front lens; Figure 7 shows a view into that lens, where you can just see the LED array.

I measured the output from the MAC 350 Entour at 8,719 lumens with a field angle of 25.1°. This is a very usable and respectable output for a small automated light consuming just over 460W, and represents a total efficacy of nearly 19lum/W. This measurement was taken after the unit had warmed up for about 30 minutes; after continuous running for a few hours so that temperatures were at their highest, the output dropped down to about 94% of this level.

The color temperature is a measured 6,600K at the beam center, and varies somewhat across the beam as you move from emitter to emitter.

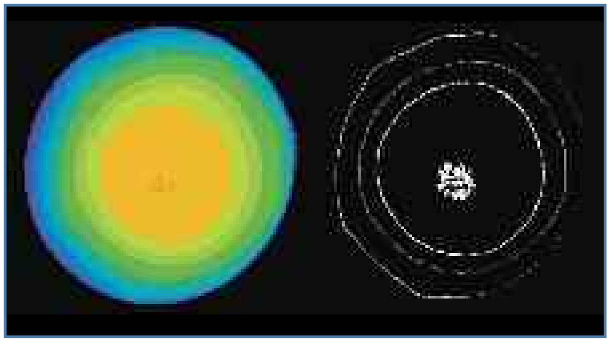
Figure 9 - Field

The beam profile is shown in Figure 8. As you can see, the beam shows a fairly flat center section and then tails off smoothly to cut off. I also captured the field with my FBA system, which shows the results shown in Figure 9. The left

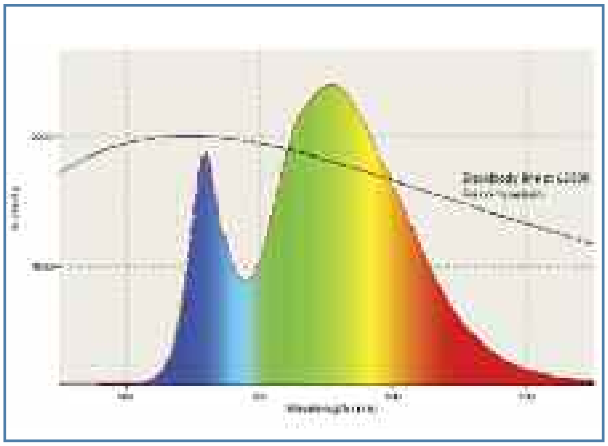
Figure 10 - Spectrum MAC 350

half of the image is a false color output showing brightness distribution, while the right half shows isolux lines connecting areas of equal brightness, a bit like a contour map. What doesn't show up in these images, but is visible to the eye, are slight lobes where the LEDs cross over and mix, which show up as some unevenness as you go around the beam. It's subtle and not a problem for this unit's intended market. Image quality is acceptable, with no chromatic aberration, but it is a little spherical. (See the gobo section of this review for more information).

I also measured the spectrum of the unit; this can be seen in Figure 10, along with a standard blackbody curve at 6,500K for comparison. The Luminous Devices LEDs, like most others, produce white light by combining the output of a blue LED with that of a yellow-green phosphor, which is excited by that same blue LED. You can see the two peaks—a narrow one in the blue around 460nm and a broader one at around 560nm—quite clearly. As with most white LEDs, this leaves a gap of reduced energy in the blue/green or cyan, and is also somewhat lacking in the reds, leading to a fairly low CRI of around 70 (Figures 9 and 10).

Dimming

The MAC 350 Entour offers a number of optional dimmer curves, selectable through either the menu or the DMX control channel. Available are linear, square law, reverse square law, and S curve. My personal preference is for square law dimmers; as this is also the standard in the MAC 350, I did all tests using this curve. Figure 11 shows the MAC Entour 350 dimming curve with the unit in square law mode. You can see that Martin did an excellent job of mapping to this curve. Dimming is smooth over the majority of the range but, in common with many LED units, there are visible steps on the bottom 10 or 20% in slow fades. PWM speed was measured at 610Hz, which, although a little slow, should be okay with most video systems. I found a problem with the way the MAC 350 responded to step changes in intensity; however, Martin tells me this is a known problem and will be addressed with a firmware update before the product ships.

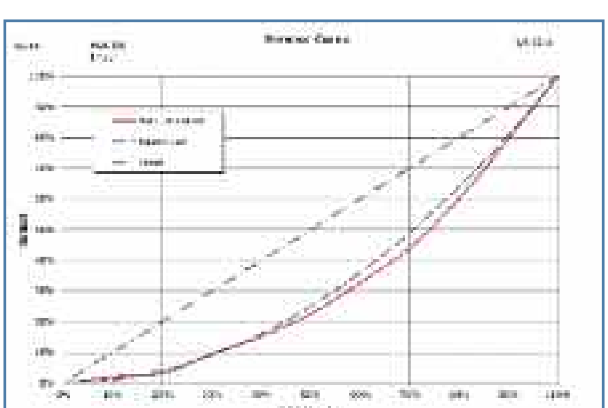

Figure 11 - Dimmer curve


Figure 12 - Gobo and color change


Figure 13 - Gobo and color


Figure 14 - Split color

Color wheel

First in line after the lamp and main aperture is the color wheel, with eight replaceable colors plus open hole. This uses the familiar Martin removable trapezoidal dichroic colors, which snap into a central hub. Removal and replacement are very simple through the small hatch door. A neat feature of this access door is the magnetic latch; it incorporates a sensor so that the unit automatically re-homes the system when the door is closed after changing

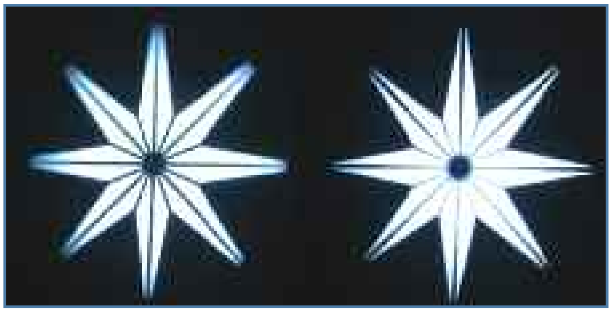
Figure 15 - Gobo focus


Figure 16 - Iris

a color or gobo. Figure 12 shows the access hatch for gobo and color change; Figure 13 shows the replaceable gobos and colors.

FIXED COLOR WHEEL

Color	Blue	Green	Orange	Yellow	Pink	Magenta	Congo	Red
Trans-mission	2.8%	36%	41%	86%	22%	5.1%	0.2%	2.1%

All colors are fairly saturated, with good output in most cases; the red and magenta outputs are a little low, probably because of the lack of red energy in the LED source.

There is a menu option in the MAC 350 Entour, allowing the user to choose whether wheels use a quick path algorithm and take the shortest route between two colors, or avoid passing through white/open hole.

COLOR WHEEL

Color change speed – adjacent	<0.1 sec
Color change speed – worst case	0.4 sec
Maximum wheel spin speed	0.53 sec/rev = 113 rpm
Minimum wheel spin speed	93 sec/rev = 0.65 rpm

Color changes and spins are all very smooth and jitter-free, with good split colors; Figure 14 shows an example of a split between red and Congo Blue. There is almost no gap between the trapezoidal colors on the wheel, which helps with these split colors.

Gobo wheel

Immediately after the color wheel is the rotating gobo wheel, with six changeable, indexable, rotating gobos plus open hole. As with the colors, these are very easy to replace; the whole assembly, complete with its planet gear, just slides in and out between two springs mounted on the wheel. Once removed from the unit, the actual gobo itself can be replaced within the gear.

There is some spherical aberration in the optical system causing slight edge-center focus difference in the gobos. Figure 15 shows the same gobo twice—the left image shows it focused on the center while the right image has it focused on the edge.

ROTATING GOBO

Gobo change time, adjacent apertures	< 0.3 sec
Gobo change time, max (Gobo 0 to 4)	0.6 sec
Maximum gobo rotate speed	0.31 sec/rev = 195 rpm
Minimum gobo rotate speed	326 sec/rev = 0.18 rpm
Maximum wheel spin speed	0.62 sec/rev = 97 rpm
Minimum wheel spin speed	630 sec/rev = 0.1 rpm

As with the color wheel, the slow rotation movement was extremely good. Positioning accuracy and hysteresis was also excellent, with a measured error of 0.07° or about 0.3" at a 20' throw.

Iris

The MAC 350 Entour has an iris mounted next to the rotating gobo wheel. These are optically close enough to each other so that it is possible to iris in on a gobo, albeit with the iris in soft focus. The iris can reduce the beam size to 17% of its full size, which provides an effective field angle of 4.4°. The amount of time required to fully open or close it was a very quick 0.1 second. The iris DMX512 channel offers some useful ramp/snap effects, which also control the LED output so that the LEDs black out during the "snap" section of the cycle. Figure 16 shows the iris.

Pan and tilt

The MAC 350 Entour has a pan range of 630° and tilt of around 290°. A full range pan move took 4.5 seconds, while a more typical 180° move finished in 2.4 seconds. Tilt took 2.7 seconds for a full move and 2.2 seconds for 180°. Positional repeatability on both pan and tilt was extremely good at 0.07°, which is around 0.3" of error at a 20' throw. Pan—but not tilt—exhibits an overshoot on full speed moves and goes past its final position by up to 6" at this throw before correcting back

Noise

The rear LED cooling fan is by far the noisiest component in the MAC 350 Entour. In "regular" fan mode, it overshadows everything else so much that I can only report the single reading of 53dbA at 1m from the fan no matter what func-

Figure 17 - Main control electronics

Figure 18 - LED supply

tion is being used. I then switched the unit to "silent" mode, which reduces the speed, and thus noise, considerably. It also reduces light output to approximately 55%. (This will vary depending on ambient temperature). In silent mode, I measured the following:

SILENT MODE SOUND LEVELS

	Normal Mode
Ambient	<35 dBA at 1m
Stationary	41 dBA at 1m
Homing/Initialization	44 dBA at 1m
Pan	48 dBA at 1m
Tilt	48 dBA at 1m
Focus	49 dBA at 1m
Color	41 dBA at 1m
Gobo	41 dBA at 1m

Electrical parameters

The MAC 350 Entour has a fully power-factor-corrected auto-ranging (100 – 240V 50/60Hz) power supply and consumed 4.08A, 463W with a power factor of 0.99 when running at full power with fans in regular mode on a nominal 115V supply. A reader wrote to me recently and suggested that I provide the quiescent power draw for LED luminaires so their energy-saving potential can be judged. I agree that's a good idea; in this case, the MAC 350 Entour consumed 0.42A, 44W with a power factor of 0.92 with LEDs off.

The initialization time from power up was approximately 37 seconds, while the time from sending a reset command through the DMX512 control channel was 26 seconds. The MAC 350 Entour is badly behaved during reset, in that that it powers the LEDs back up before the reset is finished.

Electronics and control

As with almost every unit on the market now, the electronics are distributed in multiple locations in the luminaire. The main LED and motor power supplies are in the top box; the electronics and drivers for the motor systems are mounted in one of the yoke arms (Figure 17). The other yoke arm contains what I believe is the main current drive for the LEDs while the LED dimming and temperature control is on a board mounted adjacent to the LEDs on the rear heat sink (Figure 18).

The MAC 350 Entour provides a LED character-based display and menu system offering comprehensive functions and configuration options (Figure 19). Power and five-pin XLR for DMX512 data come into a connection panel on the opposite side of the top box (Figure 20). I had thought for a moment that these weren't labeled; however, the labeling and fuse information is on the underside of the top box adjacent to the panel.

Construction

The construction is very familiar, following Martin's usual mix of sheet steel chassis with injection-molded covers and die-cast heat sink to form an attractive and well-made unit. The main optical module is easily removed and slides out as a complete unit for cleaning and maintenance (Figure 21). The LEDs are buried deep in the

Figure 19 - Menu

Figure 20 - Connections

Figure 21 - Optical module

unit, and are clearly not intended to be user-replaceable. If they really do last 60,000 hours, then that is no problem at all.

Conclusions

That's about it for the MAC 350 Entour. I'm delighted to have measured my first LED-based spot, but I'm quite sure it won't be the last. The unit demonstrates very clearly that not only are LED-based spot units possible, but they can also compete strongly with conventional sources. It's a very attractive concept to never have to change a lamp during a product's lifetime, particularly when you're talking about permanent installs and architectural uses. The proof of that concept will be the reliability and longevity of the LEDs and their drive electronics. Only time will tell.

As always with these reviews, I hope I've provided enough basic information and measurements for you to judge if the MAC 350 Entour might be interesting in your application. If so, then don't stop here; use this as a basis for your own investigations and tests.

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