Confidential: Preliminary Test Results:
ReptileUV Prototype Metal Halide Lamp

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Introduction/ product description

Three prototype metal halide lamps were submitted to UV Guide UK by Robert MacCargar of ReptileUV between January and March 2008.

Fig. 1

The lamp is a PAR-38 reflector lamp with a moulded spreader lens on the surface and a slightly milky inner coating. (Fig. 1.) It has a brass collar and an E27 screw fitting.
It is an externally-ballasted 70watt metal halide; the lamp and a matching ballast box are supplied as a kit.
The lamp can be used in any suitable lamp holder with a heat-resistant ceramic fixture rated as suitable for a metal halide lamp; in practice this means a lamp holder with good terminal connections and fairly short lead, as these lamps require an extremely high voltage starting pulse from the ballast.
The lamps were given the identification numbers BMH11, BMH12 and BMH13.
The first lamp (ref. BMH11 – inscribed L3 on the collar) had already been in use for approximately 1,000 hours and was sent with the following information:
Initial output 123μW/cm^2 at 12 inches. Output after 1,000 hours: 115 to 130 μW/cm^2 at 12 inches.
The other two lamps were brand new and inscribed 231107F (BMH12) and 231107W (BMH13) on their collars.

Test Results

Each lamp was installed in a suitable ceramic lamp-holder with no reflector or dome, positioned vertically, lamp facing downwards. Recordings were all taken from below the lamp, with distance measurements taken from the closest part of the lamp surface to the sensor. Because the beam is rarely orientated perfectly along the axis of the lamp, the readings were all taken at the point where the highest reading was located; i.e. directly in the centre of the beam, at each distance – rather than directly perpendicular to the lamp face. The angle of the beam was not, however, found to be significantly far from the central axis in any of the lamps tested.
First meter recordings were taken after 30 minutes warm-up and spectrograms were taken after 1 hour of use.
Recordings included:

- Total UVB - 280 - 320nm (*Solarmeter 6.2 broadband UVB meter*)
- UV Index (UVB in the biologically active range of wavelengths) (*Solarmeter 6.5 UV Index meter*)
- UVC (*Solarmeter 8.0 broadband UVC meter*)
- Visible light output (*SkyTronic LX101 model 600.620 digital lux meter*)
- Electrical consumption (*Prodigit power monitor model 2000M-UK*)

• Spectrograms (*Ocean Optics Inc*. *USB2000 spectral radiometer with a UV-B compatible fibre-optic sensor with cosine adaptor*)

The monitoring of initial decay - "burning-in" over the first 100 hours – was then begun in the established pattern for the two new lamps; recordings of the total UVB output are taken at 3 hours and at 15 hours, and then the lamp is put on a schedule of 15 hours use each day until a 105 hour burn is completed and a final set of recordings is made.

The lamp which had already been in use for 1,000 hours was placed on a longer-term testing regime and recordings were taken after a further 250 and 500 hours of use.

Total UVB - 280 - 320nm

Recordings of the output of the lamps were made with the Solarmeter 6.2 broadband UVB radiometer. Their total UVB output at the beginning and end of each test period is shown in Figure 2a. Figure 2b gives the data from each lamp in table form.

Fig. 2a

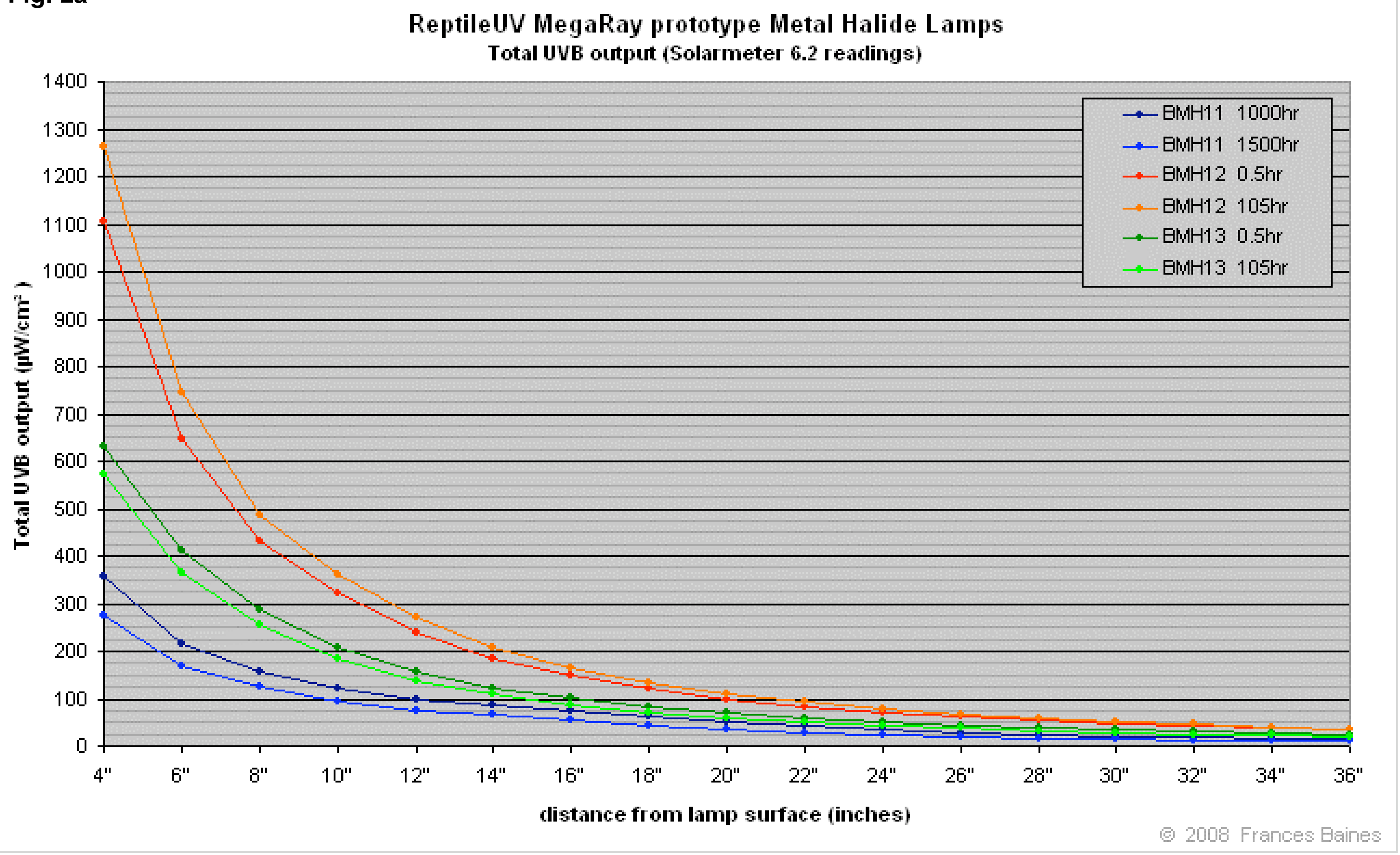


Fig. 2b. Total UVB during burning-in and longer-term testing (μW/cm²)																	
	Distance from lamp surface (inches)																
	4	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**
BMH11 at 1,000hr	356	214	158	123	100	85	74	62	50	42	34	29	24	21	19	17	15
at 1,500hr	275	170	124	95	76	66	55	43	35	29	24	20	17	15	13	12	11
BMH12 at 0.5hr	1104	646	432	321	238	185	149	121	100	84	72	62	53	46	42	38	34
at 105hr	1262	744	485	360	269	206	166	135	110	93	78	67	59	52	46	40	36
BMH13 at 0.5hr	632	411	287	209	157	123	101	84	70	60	52	45	40	35	31	28	25
at 105hr	571	366	255	184	139	108	88	72	60	51	44	38	33	29	25	22	20

These lamps are emitting high levels of UVB, but each lamp has a very different output and rate of decay.

Initial Decay

Lamp BMH13 showed a small initial decay of 14.7% in total UVB output in the first 105 hrs of use (figures averaged across all distances from 4 to 36 inches) whereas lamp BMH12 did not, apparently, decay at all; in fact its output went up slightly, with an overall gain of 10.8%. This is extremely unusual; with most UVB lamps, as the glass of both inner arc tube and outer envelope undergoes initial UV bombardment, there is an immediate decay in output as the glass becomes solarised.

Closer investigation of the data reveals that both the lamps went through an initial marked increase in output which reached a maximum within 3 hours with lamp BMH13 but which took about 75 hours with BMH12, followed by the onset of a slower, steady fall. Presumably this occurs as the halide compounds settle into use. However, the initial increase in output was greater with lamp BMH12, and had not dropped below the initial values after 105 hours. This can be clearly seen in figures 2c and 2d (below), which chart the initial decay seen at each distance, with each lamp.

Long-Term Decay

Lamp BMH11 showed a decay of 26.9% in total UVB output over 500 hours of use (figures averaged across all distances from 4 to 36 inches). This is a fairly high rate of decay for a lamp which is fully burned in, but longer-term studies are needed to find out whether this rate of decay remains constant, or slows down in the same way as that seen in some mercury vapour lamps.

Fig. 2c

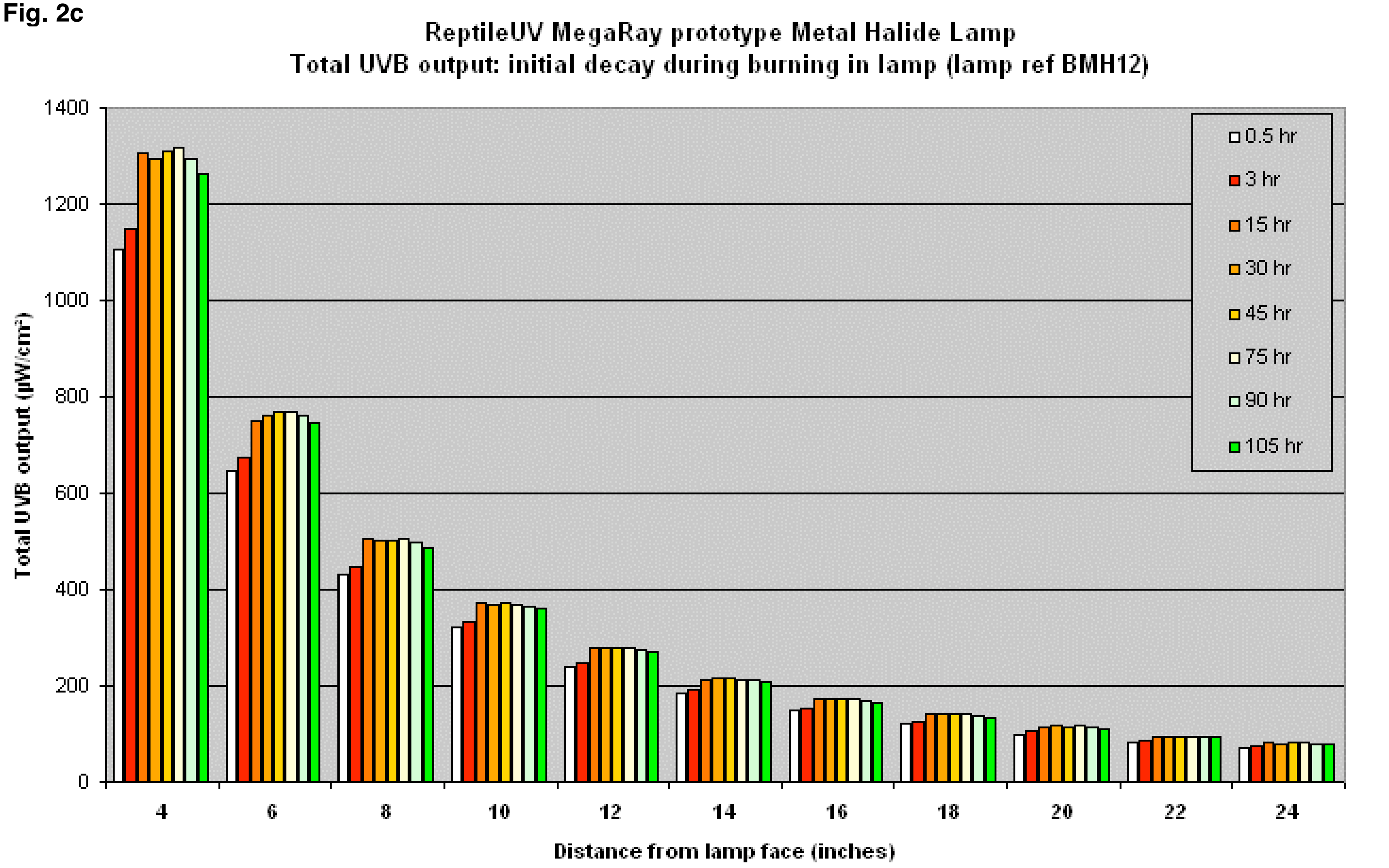
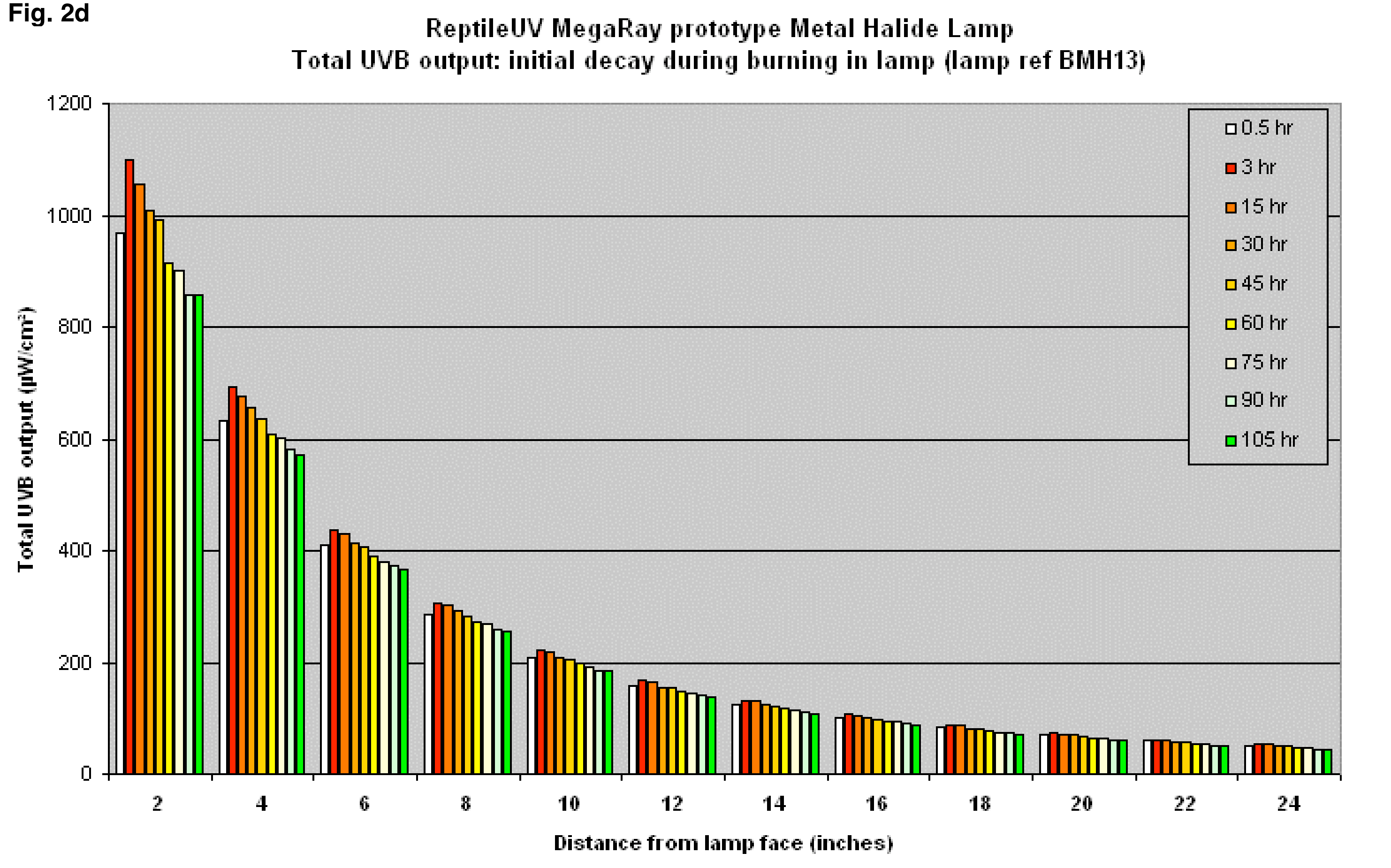

ReptileUV MegaRay prototype Metal Halide Lamp
Total UVB output: initial decay during burning in lamp (lamp ref BMH12)
Total UVB output (µW/cm²)
1400
1200
1000
800
600
400
200
0
4
6
8
10
12
14
16
18
20
22
24
Distance from lamp face (inches)
0.5 hr
3 hr
15 hr
30 hr
45 hr
75 hr
90 hr
105 hr

Fig. 2d



It is tempting to compare the total UVB output of a lamp (as measured with a broadband UVB meter) with that of natural sunlight, in order to assess its suitability, ascertain a safe basking distance for the lamp, and estimate its ability to facilitate vitamin D3 production. Unfortunately, unless the spectral power distribution of the lamp is known to be very similar to sunlight, this is not a valid procedure. Broadband meters have sensors with a fixed sensitivity response and are calibrated to a specific spectrum; the Solarmeter 6.2 is calibrated for commercial human tanning tubes and other lamps with UVB spectral power distribution somewhat similar to the sun. Because of this, lamps with a very different spectral power distribution will not produce a comparable response.

But much more importantly, a broadband UVB meter cannot give any indication of what percentage of the total UVB is in the more biologically active, lower wavelengths. Therefore, a simple comparison of the readings from a broadband meter from the sun and from a UV lamp may be extremely misleading as regards the potential of the lamp to enable the synthesis of vitamin D3 or even to cause cell damage or photo-kerato-conjunctivitis. Therefore it is useful to assess, in addition, how much of the UVB is in the more biologically

active, lower wavelengths, and how the output of the lamp at different distances would compare to natural sunlight. This can be estimated by measuring the UV Index (UVI) of light from the lamp at various distances.
The Solarmeter 6.5 UV Index radiometer has a sensor response which follows the Diffey Erythemal Action Spectrum effective irradiance (Eeff), which closely follows the vitamin D action spectrum (Deff) in the UVB range (280 - 320nm). Because of this narrow range of sensitivity, this meter is much less affected by the differing spectral power distributions of different lamps and the sun, enabling reasonable comparisons to be made. However, the amount of light emitted by a lamp at these wavelengths is often very small indeed, hence the meter may be operating close to the limits of its resolution as the distance from the lamp increases. This is one reason for measuring output with both a broadband UVB meter and a UV Index meter.

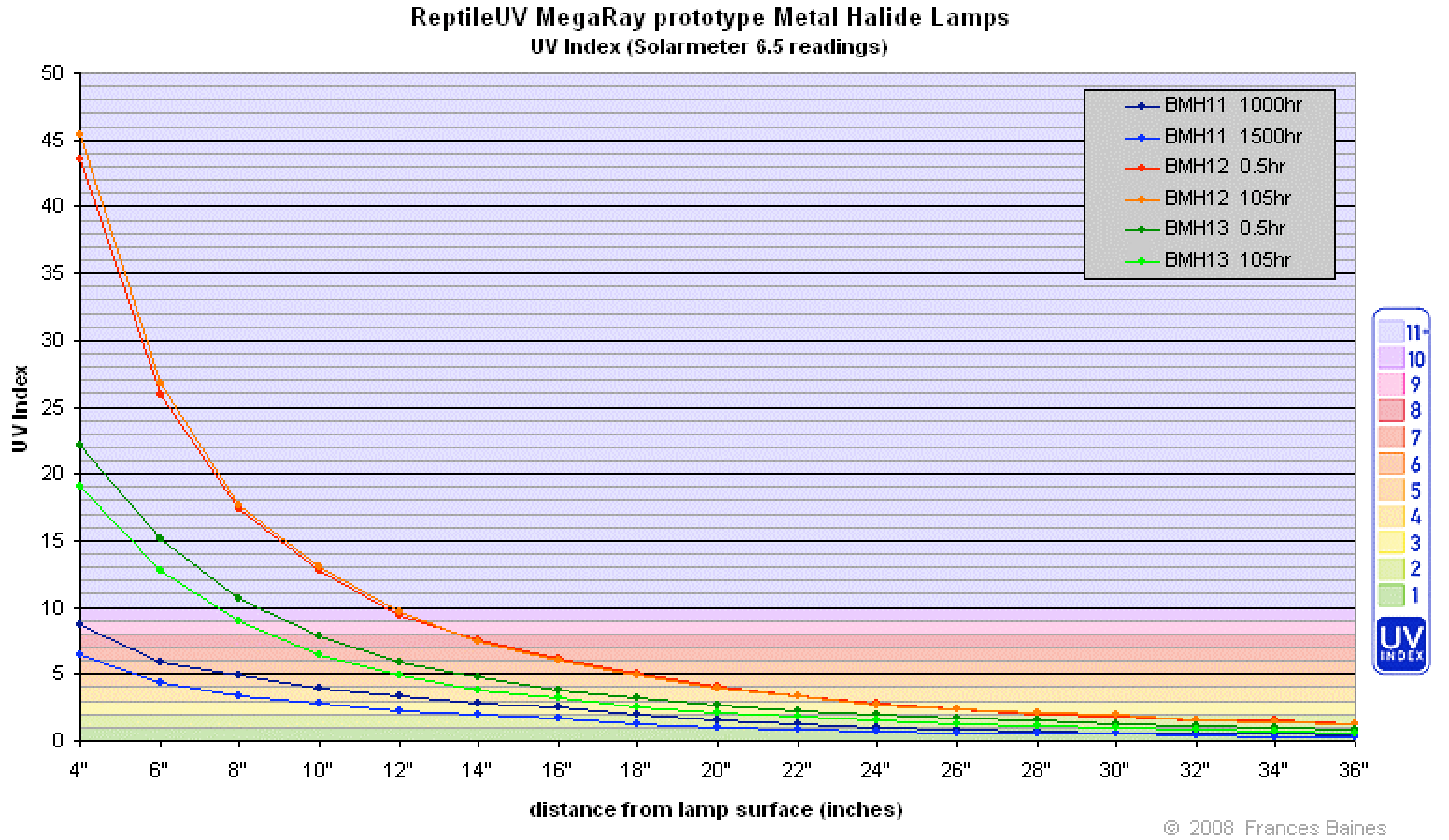
The UV Index

Figures 3a and 3b (below) give the results of recordings taken with the UV Index meter, simultaneously with those in Figures 2a and 2b. Figure 3a gives the data in numerical form, from 4 to 36 inches distance. The chart (Figure 3b) is colour-coded to an approximation of the international UV Index colour system designed for reporting solar UV levels.

Fig. 3a. UV Index during burning-in and longer-term testing

	Distance from lamp surface (inches)																
	4	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**
BMH11 at 1,000hr	8.7	5.9	4.9	3.9	3.4	2.8	2.5	2	1.5	1.3	1	0.8	0.7	0.6	0.5	0.5	0.4
at 1,500hr	6.5	4.4	3.4	2.8	2.3	1.9	1.7	1.3	1	0.8	0.7	0.6	0.5	0.5	0.4	0.3	0.3
BMH12 at 0.5hr	43.6	25.9	17.4	12.7	9.4	7.5	6.1	5	4	3.3	2.8	2.4	2	1.8	1.6	1.5	1.3
at 105hr	45.4	26.8	17.7	13	9.7	7.4	6	4.9	3.9	3.3	2.7	2.4	2.1	1.9	1.6	1.4	1.3
BMH13 at 0.5hr	22.1	15.1	10.7	7.8	5.9	4.7	3.8	3.2	2.6	2.3	1.9	1.7	1.5	1.3	1.1	1	0.9
at 105hr	19.1	12.8	8.9	6.4	4.9	3.8	3.2	2.5	2.1	1.8	1.5	1.3	1.1	1	0.8	0.7	0.6

Fig. 3b



The UVI is a particularly useful measurement because it is familiar to many people from its use in weather forecasts and "safe sunbathing" campaigns. Early or late in the day, when the sun is low in the sky, or in bright overcast weather, or in winter in northern latitudes, the UVI may never exceed 1 or 2. As the sun rises in the sky, the UVI increases steadily until in temperate latitudes, a summer high of 8 or 9 may be recorded; in the tropics this may rise to 13 or 14 at mid-day. A UVI of 15 -16 is equivalent to the most intense sunlight at sea level anywhere on earth. A UVI above 8 is designated "very high" by the World Health Organisation.

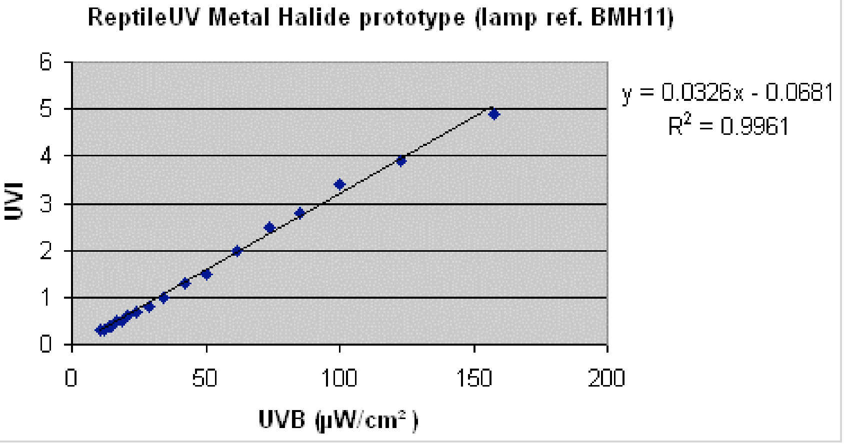
A small number of recordings taken in the field, alongside basking lizards in the tropics - usually seen in early to mid-morning or from mid-afternoon onwards - suggest that reptiles which bask in full sun choose times of day when UV levels are lower, often around UVI 2 to 3 - the highest recorded UVI, for example, being only 7.6 in a small study which I conducted in Australia. Most reptiles only spend short periods of time in full sun; once their body temperatures are optimal they tend to move in and out of light shade or shelter, where the UVI may be much lower. Recordings taken within a tropical rainforest at mid-day in fine weather varied from 0.1 to 2.4 under the trees, whereas in a small clearing where some sun reached the forest floor, a UVI of 9.0 was recorded.

The output of these prototype lamps varies considerably, very much in line with their total UVB output.
Lamp BMH11 appears to be similar to early morning sunshine before 9am in the tropics, at reasonable basking distances. At 12 to 16 inches from the lamp, the UVI is somewhere between 3.5 and 2.5 after 1000 hours of use.
Lamp BMH13 has a higher output; after 105 hours, the UV Index at 12 to 16 inches is between 3 and 5 at the centre of the beam. This is equivalent to morning sunlight before about 9.30am in the tropics.
The highest output of all was from lamp BMH13. After 105 hours this lamp was giving a UV Index between 6 and 10, from 12 to 16 inches beneath it. This is equivalent to late morning tropical sunlight, from about 10 – 11am, and might be too high for species which normally bask early in the day. This lamp might be more suitable for species with lower UV requirements, however, if positioned at a greater distance. For example, at 24 inches, a UV Index of just under 3.0 is still available.

Initial and Longterm Decay in terms of the UV Index
The solarisation of glass under UV light normally affects the transmission of shorter wavelengths more strongly, and hence the shorter wavelength UVB which is responsible for vitamin D3 synthesis usually decays slightly faster than the overall decay of total UVB output. This is indeed the case with these lamps. The UV Index recordings from lamp BMH11 after 1,500 hours use are 29.3% lower than at 1,000 hours (compared with a 26.9% loss in total UVB). After 105 hours of use, the UV Index readings from lamp BMH12 have increased by just 0.5% (compared with a 10.8% increase in total UVB) and BMH13 has decayed by 21.4% (compared with a 14.7% loss in total UVB).

Relative Photobiological Activity
A simple, "rough-and-ready" estimation of the photobiological activity of the light emitted by a lamp can be made by comparing its UV Index reading with that of natural sunlight when the total UVB output of both is the same. It is only a crude estimation because (as discussed earlier) broadband meters have a fixed sensor response affected by differing spectral power distributions. It has proven invaluable in the field, however, for detecting lamps with a dangerously high proportion of their output in the very low UVB wavelengths.
The following results were obtained by regression analysis of paired Solarmeter 6.2 and 6.5 readings
100 μW/cm² total UVB from the MegaRay Metal Halide prototype
BMH11 ≡ UVI 3.2 (figure 4a, right)
BMH12 ≡ UVI 3.6 (figure 4b, below)
BMH13 ≡ UVI 3.5 (figure 4c, below)

Fig. 4a



and for comparison,
100 μW/cm² total UVB from sunlight (UK and Australia) ≡ UVI 1.6 – 2.0 (depending upon solar altitude and degree of cloud cover)
100 μW/cm² total UVB from a MegaRay EB Mercury Vapour Lamp ≡ UVI 3.7

Fig. 4b

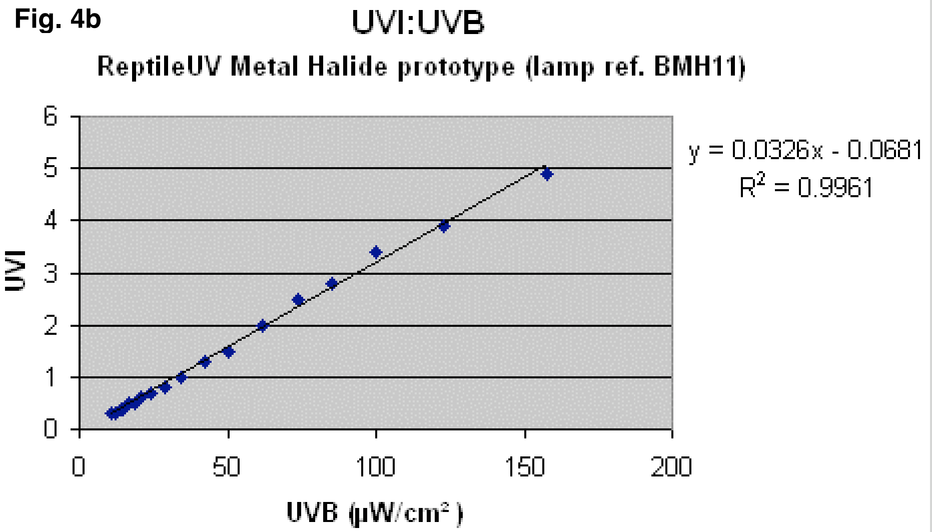
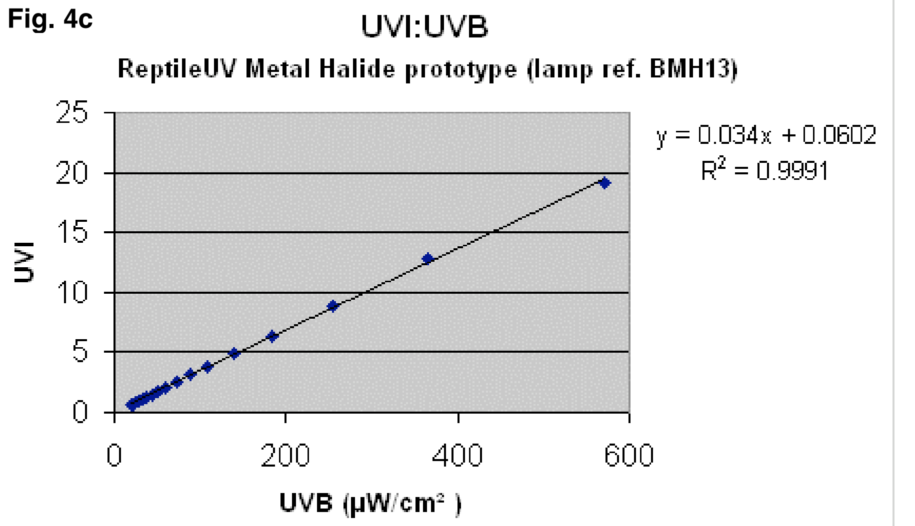


Fig. 4c



This suggests that the light from the metal halide lamps (and the mercury vapour lamp) is 1.5 – 2x as photobiologically active as natural sunlight. High-output fluorescent tubes, such as the ZooMed Reptisun 10.0 tube, and most other mercury vapour lamps such as the ZooMed Powersun and T-Rex Active UV Heat Flood lamp give similar results. There would not appear to be an excessively disproportionate amount of low-wavelength UVB emitted by any of these lamps.

Iso-irradiance Charts (Beam "spread charts")

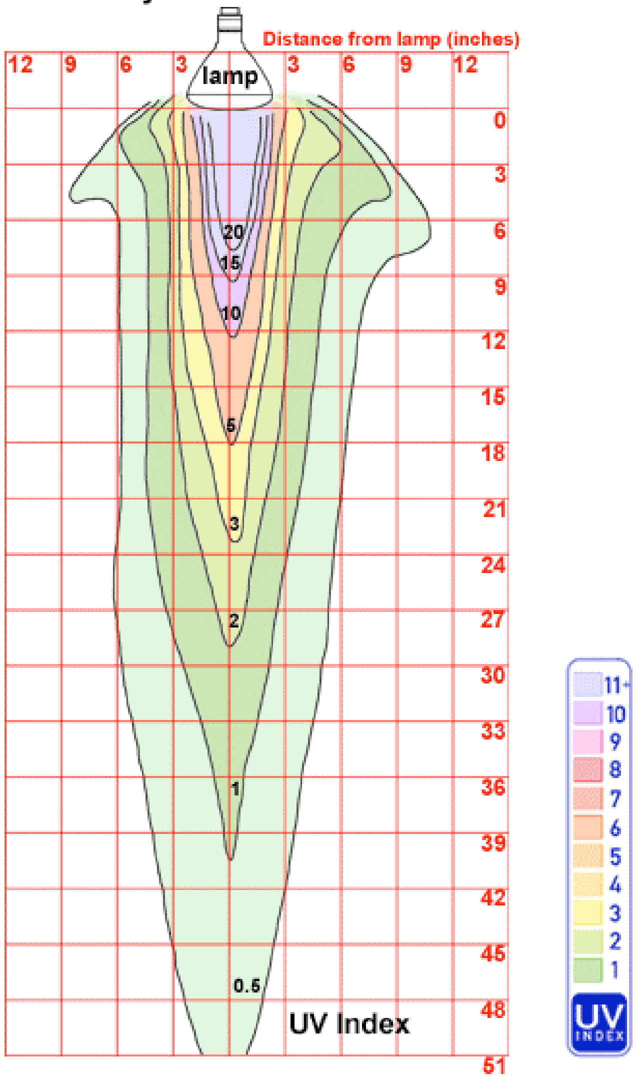
In the vivarium, the shape of the UVB beam from a lamp, and the UVB gradient which it creates, is very important. The beam must be wide enough for the reptile to place most, if not all of its body within the zone of effective UVB radiation at a suitable basking distance. Iso-irradiance charts ("spread charts") for the UV Index were constructed for the two new lamps after burning-in, according to the method previously devised by the current author. (Figures 5a and 5b)

Both lamps have symmetrical, fairly narrow UVB beams extending a considerable distance beneath the lamp. 12 inches below the lamp, the "footprint" of the stronger lamp, BMH12, is about 10 inches wide with a UV Index from 1.0 at its circumference to 10.0 in the centre; at 18 inches distance, the footprint is still about 9 inches wide and has a UV Index gradient from 1.0 to 5.0.

The less powerful lamp, BMH13, has a 6-inch wide footprint at 12 inches distance, with a UV gradient from 1.0 to 5.0.

Fig. 5a

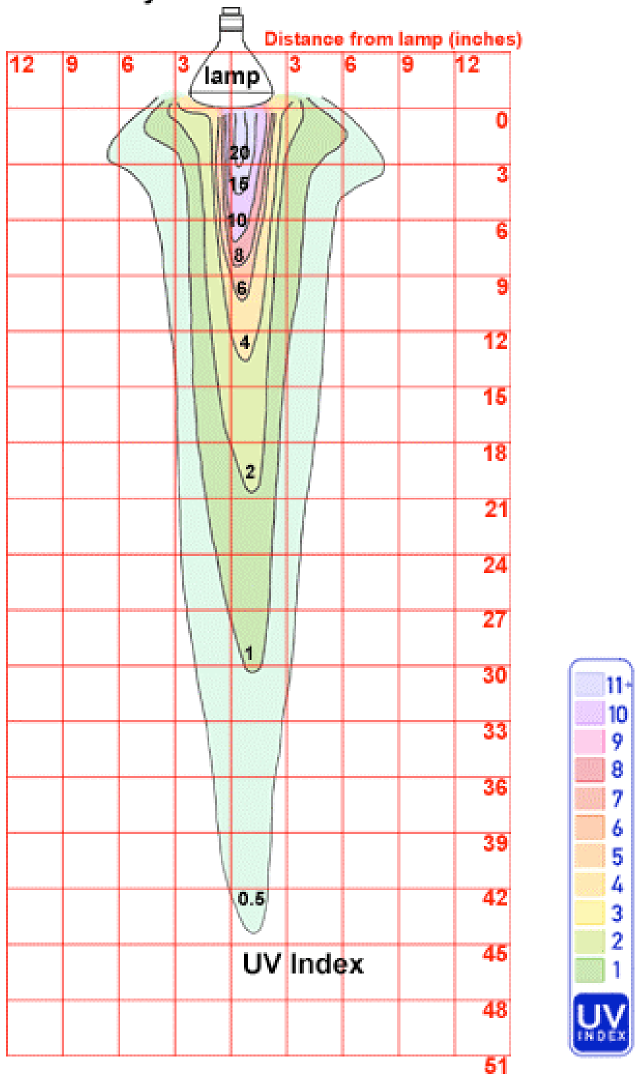
ReptileUV.com Mega-Ray Metal Halide UVB Lamp
Externally Ballasted 70watt bulb



UV Index iso-irradiance diagram (spread pattern)
of lamp ref. BMH12 tested 23.05.2008
after 110 hours burn

Fig. 5b

ReptileUV.com Mega-Ray Metal Halide UVB Lamp
Externally Ballasted 70watt bulb



UV Index iso-irradiance diagram (spread pattern)
of lamp ref. BMH13 tested 10.09.2008
after 107 hours burn

UVC

Recordings were made with the Solarmeter 8.0 broadband UVC radiometer measuring the UVC range (240 – 280nm) in combination with a WG295 filter to eliminate stray light effects from the intense UVA emitted by these lamps. Test results indicated zero UVC output from all three lamps.

Visible light output

Recordings with a lux meter (SkyTronic LX101 model 600.620 digital lux meter) confirm the visual impression that the lamps produce **extremely effective, intense illumination**. Figure 6a gives the data in numerical form, from 2 to 36 inches distance. The chart (Figure 6b) gives the full range of measurement to 50 inches distance.

At 12 inches, BMH11 is emitting approximately 70,000 lux and the two new lamps are emitting 110,000 – 120,000 lux.

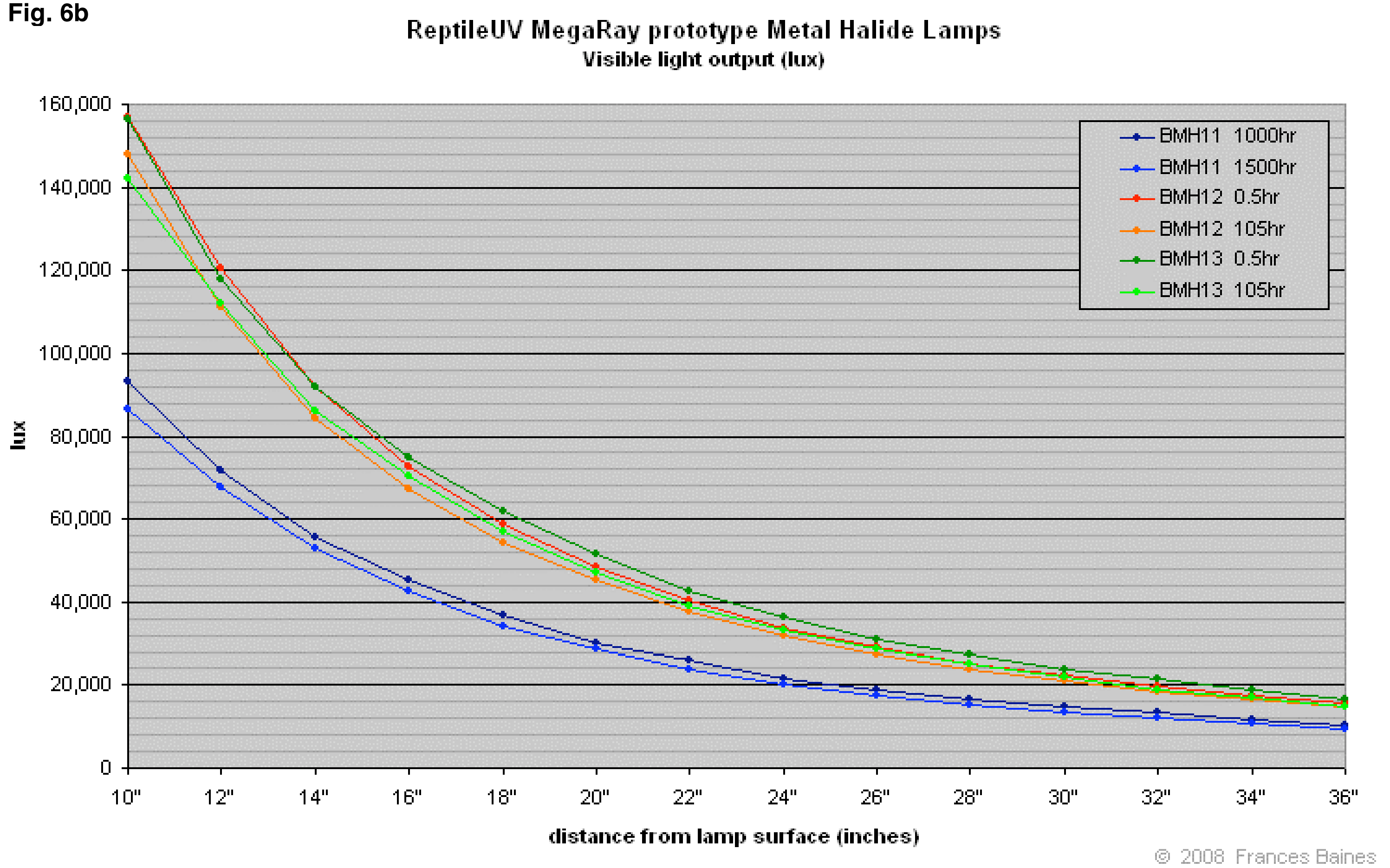
For comparison, direct solar readings (the meter sensor pointing directly at the sun) five minutes after sunrise reach 3 – 5,000 lux. Levels of 50,000 are reached within half an hour, and 100,000 lux is often recorded 2-3 hours later. In clear weather, mid-day direct solar readings of 120,000 to 150,000 lux are often seen. **Hence, these metal halide lamps produce the equivalent of full morning sunlight at 12 inches distance.**

In contrast, a typical 18-20watt UVB fluorescent tube produces around 500 lux at 12 inches distance, and a typical MegaRay 100watt mercury vapour lamp produces between 12,000 – 16,000 lux at 12 inches.

Fig. 6a. Visible light output (lux) during burning-in and longer-term testing

	Distance from lamp surface (inches)														
	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
BMH11 at 1,000hr	124,600	93,000	71,800	55,700	45,400	36,700	30,200	25,800	21,700	18,800	16,500	14,800	13,400	11,800	10,400
at 1,500hr	116,800	86,400	67,700	53,000	42,500	34,100	28,500	23,900	20,300	17,500	15,300	13,600	12,300	10,900	9,600
BMH12 at 0.5hr	Off scale	157,000	120,500	92,100	72,800	58,500	48,200	40,200	33,700	29,000	25,200	22,200	19,800	17,600	15,500
at 105hr	Off scale	148,100	111,200	84,400	67,300	54,200	45,100	37,600	31,900	27,400	23,900	21,200	18,300	16,500	14,800
BMH13 at 0.5hr	Off scale	156,400	118,000	92,100	74,700	62,000	51,400	42,800	36,500	31,100	27,300	23,800	21,400	18,700	16,500
at 105hr	Off scale	142,100	112,200	86,200	70,300	57,100	47,200	39,200	33,200	28,700	25,200	22,100	19,000	16,900	15,000

Fig. 6b



Electrical consumption

The power consumption of each lamp was measured with the Prodigit power monitor model 2000M-UK. (Figure 7) These readings include the power consumption of the ballast. The lamps are all operating exactly as specified.

Figure 7. Power consumption	Amps	Watts	VA (VrmsArms)	Pf
BMH11 (1,000hrs use)	0.30	68	69	0.99
BMH12 (105 hrs use)	0.31	69	69	1.00
BMH13 (105 hrs use)	0.30	69	69	0.99

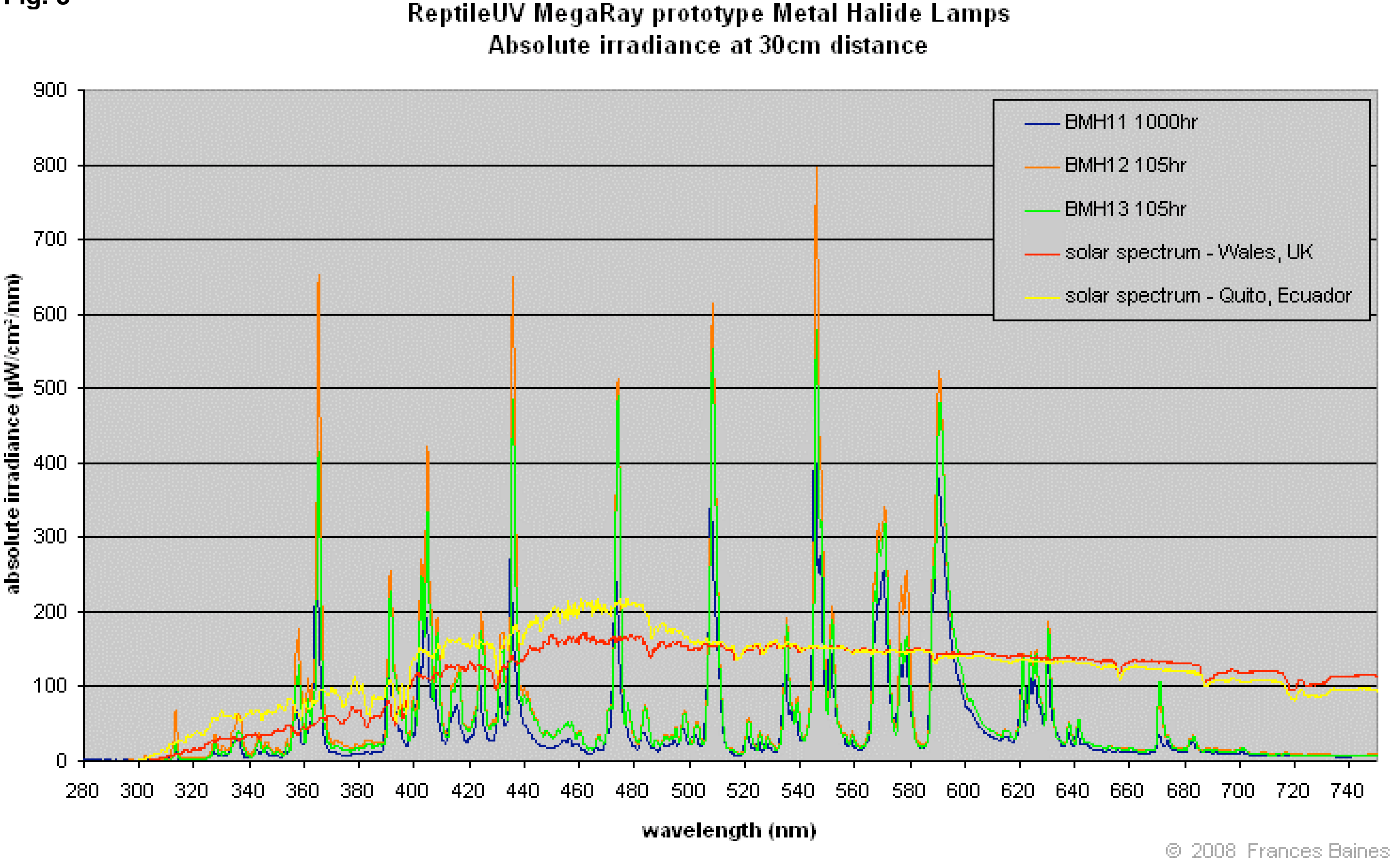
Spectral Analysis.

Total UV-VIS output

The full UV-VIS (UltraViolet plus Visible) spectrum of all three lamps, recorded at 30cm, is shown in Figure 8. For comparison, overlaid are the spectra obtained from mid-day sunlight with the sun at its highest, close to sea level at the June solstice in the Northern Hemisphere (Wales, UK) and at high altitude at the Equator at the September equinox (Quito, Ecuador).

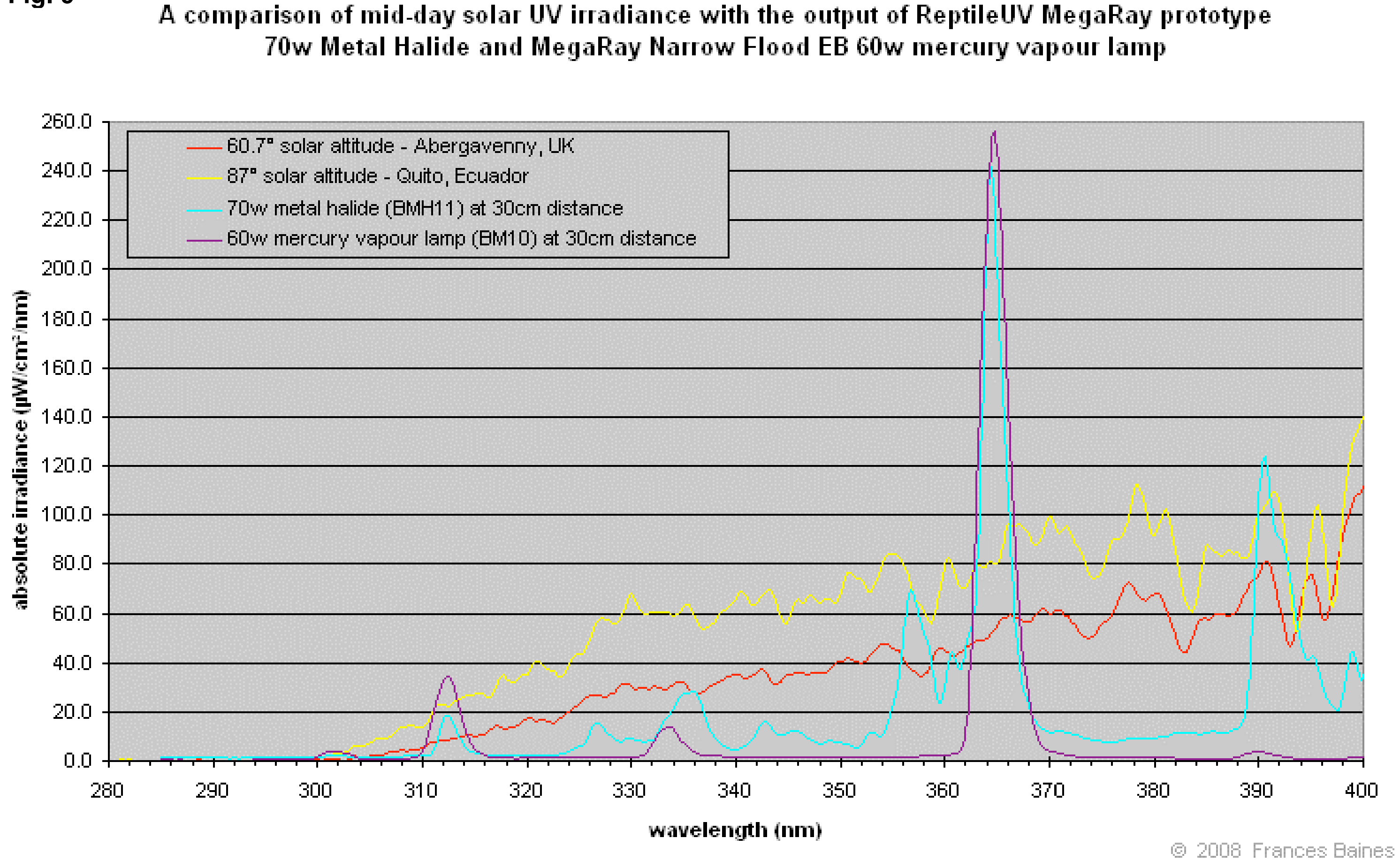
The lamps have a typical spectral power distribution for a metal halide lamp, and all three lamps clearly have the same halide blend. The "spikes" generated by the mercury vapour and halide compounds produce irradiance across all wavelengths, providing very intense light across almost the entire UV-VIS spectrum.

Fig. 8



UV Output. Figure 9 shows the UV spectra of lamp BMH11 and the solar spectra in more detail, and in comparison with a typical mercury vapour lamp, the ReptileUV MegaRay EB 60W lamp.

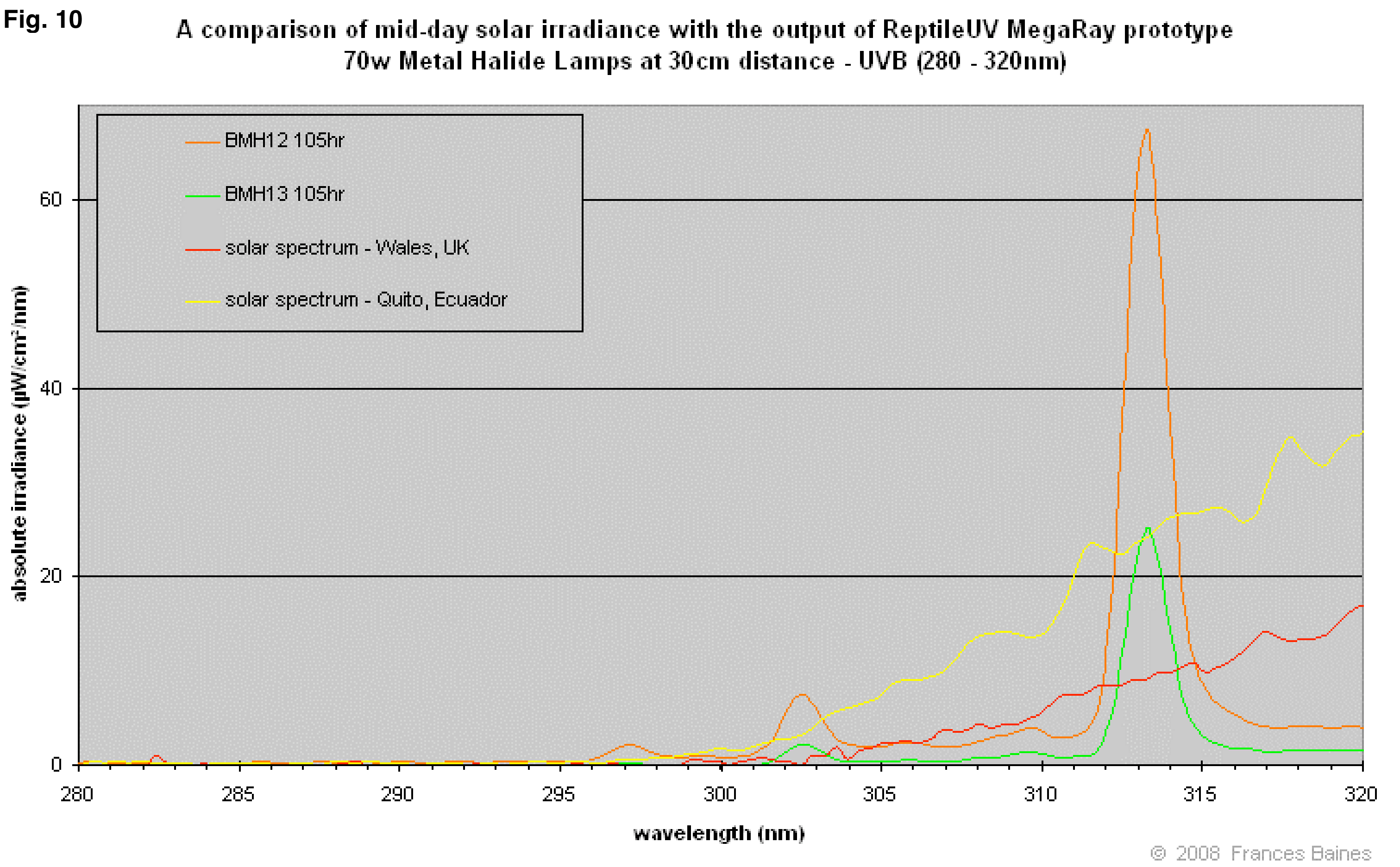
Fig. 9



One of the advantages of metal halide lamps over mercury vapour lies in the former's ability to produce emissions at wavelengths between the mercury "spikes". In the UVA range, the very intense spike of radiation from the mercury vapour at 365nm occurs in both lamp types, and is within the range visible to reptiles (above 350nm). However, UVA is emitted in considerable amounts across all UVA wavelengths from the metal halide. In theory at least, this should improve the colour rendering of the lamp to reptile eyes. Moreover, short wavelength UVA, although not visible to reptiles, is involved in the control of vitamin D3 synthesis and its presence in greater amounts than in the mercury vapour lamp makes the spectrum considerably more sun-like.

As with sunlight, the amount of UVB emitted by metal halide lamps is very small when compared with longer wavelengths and is more easily visualised on a separate chart (Figure 10)

Fig. 10



The threshold wavelength is around 297nm, which is close to the threshold for equatorial sunlight, and there is no emission below 295nm, hence no hazardous UVC or short-wavelength UVB. Significant UVB in the range that enables vitamin D3 synthesis – up to 315nm - is produced by all the lamps including BMH11 (not shown on this chart). The peak at around 303nm is especially important, as this wavelength is well within the action spectrum for vitamin D3 synthesis.

Additional information obtained from the spectral data

Percentage analysis

Analysis of the spectral data enables comparison of the percentages of UVB, UVA and visible light.

Figures 9a and 9b give the irradiance in μW/cm² for UVB, UVA and visible light from the lamp (integrated spectral data), together with the percentages of the total. The definitions for the wavelength ranges in Figure 11a are those widely used in photobiological studies and generally accepted in the USA; in Figure 11b, they are those defined by the IEC.

Figures for direct summer UK sunlight are shown for comparison.

Fig. 11a. Spectral analysis (USA parameters)	Absolute irradiance (μW/cm²)			% of total irradiance		
	UVB (280-320nm)	UVA (320-400nm)	Visible (400-750nm)	% UVB	% UVA	%Visible
BMH11 Metal Halide 1000hr at 30cm	98.1	2221.8	17863	0.5	11.0	88.5
BMH12 Metal Halide 105hr at 30cm	188.2	4401.0	25762	0.6	14.5	84.9
BMH13 Metal Halide 105hr at 30cm	51.9	3300.8	23502	0.2	12.3	87.5
Direct solar recording (clear sky) Wales UK 7 July 07 12:10GMT solar altitude 60.8deg	246.6	3851.5	47946	0.5	7.4	92.1

Fig. 11b. Spectral analysis (IEC parameters)	Absolute irradiance (μW/cm²)			% of total irradiance		
	UVB (280-315nm)	UVA (315-400nm)	Visible (400-750nm)	% UVB	% UVA	%Visible
BMH11 Metal Halide 1000hr at 30cm	86.2	2234.1	17863	0.4	11.1	88.5
BMH12 Metal Halide 105hr at 30cm	166.0	4424.1	25762	0.5	14.6	84.9
BMH13 Metal Halide 105hr at 30cm	43.7	3309.3	23502	0.2	12.3	87.5
Direct solar recording (clear sky) Wales UK 7 July 07 12:10GMT solar altitude 60.8deg	154.4	3941.0	47946	0.3	7.6	92.1

These results show that the percentages of UVB, UVA and visible light produced by these lamps are remarkably similar to those seen in natural sunlight. This is in marked contrast to many other artificial light sources, most of which emit a far lower percentage of visible light.

Fig. 12. Colour analysis				
	BMH11 Metal Halide 1000hr at 30cm	**BMH12 Metal Halide 105hr at 30cm**	**BMH13 Metal Halide 105hr at 30cm**	**Direct solar recording (clear sky) Wales UK 7 July 07 12:10GMT**
Color Mode	Emissive	Emissive	Emissive	Emissive
X	82.41	99.2	90.36	141.65
Y	83.55	96.78	87.9	146.1
Z	53.21	80.37	73.17	144.7
x	0.376	0.359	0.3594	0.3276
y	0.3812	0.3502	0.3496	0.3378
z	0.2428	0.2908	0.291	0.3346
CRI Ra	**63.7 (4153K)**	**69.8 (4481K)**	**72.8 (4462K)**	**98.5 (5723K)**
CRI R1	57.8 (4153K)	62.7 (4481K)	67.7 (4462K)	97.9 (5723K)
CRI R2	77.4 (4153K)	85.1 (4481K)	88.9 (4462K)	98.3 (5723K)
CRI R3	87.8 (4153K)	88.3 (4481K)	86.2 (4462K)	99.4 (5723K)
CRI R4	60.6 (4153K)	66.2 (4481K)	70.4 (4462K)	98.2 (5723K)
CRI R5	59.2 (4153K)	71.7 (4481K)	76.9 (4462K)	97.9 (5723K)
CRI R6	66.4 (4153K)	87.9 (4481K)	93.4 (4462K)	97.9 (5723K)
CRI R7	70.8 (4153K)	68.3 (4481K)	68.2 (4462K)	99.7 (5723K)
CRI R8	30.0 (4153K)	28.1 (4481K)	30.6 (4462K)	98.7 (5723K)
CRI R9	-95.9 (4153K)	-93.0 (4481K)	-81.0 (4462K)	95.5 (5723K)
CRI R10	43.6 (4153K)	70.9 (4481K)	80.2 (4462K)	96.8 (5723K)
CRI R11	54.6 (4153K)	66.9 (4481K)	72.4 (4462K)	97.7 (5723K)
CRI R12	52.4 (4153K)	81.0 (4481K)	85.7 (4462K)	96.6 (5723K)
CRI R13	64.4 (4153K)	69.2 (4481K)	74.1 (4462K)	97.8 (5723K)
CRI R14	93.2 (4153K)	92.5 (4481K)	91.4 (4462K)	99.7 (5723K)
CRI DC	3.40E-03	6.04E-03	6.50E-03	2.68E-03
DC<5.4E-3	TRUE	FALSE	FALSE	TRUE
CCT	**4153K**	**4481K**	**4462K**	**5723K**
u'	0.2205	0.2214	0.222	0.2048
v'	0.5029	0.4861	0.4858	0.4752
w'	0.2767	0.2925	0.2922	0.3201
u,v hue-angle	-148.9 degrees	-132.1 degrees	-131.5 degrees	-136.2 degrees
u,v saturation	0.539	0.67	0.668	0.923
Dominant Wavelength	488.3 nm	482.7 nm	482.5 nm	484.2 nm
Purity	0.182	0.24	0.24	0.32
CIE Whiteness	-47.4	39.6	33.7	147.9
CIE Tint	-12.74	-16.67	-16.95	8.08
Hunter L	91.4	98.4	93.8	120.9
Hunter a	1	7.8	8	-2.3
Hunter b	29.5	20.4	19.4	13.6
CIE L*	93.3	98.7	95.1	115.6
CIE a*	-16.6	-11.3	-10.5	-23.1
CIE b*	-40.3	-64.6	-62.8	-92.3
CIELAB hue-angle	-112.4 degrees	-99.9 degrees	-99.5 degrees	-104.1 degrees
CIELAB chroma	43.6	65.6	63.6	95.1
CIE1960 u	0.2205	0.2214	0.222	0.2048
CIE1960 v	0.3353	0.324	0.3239	0.3168

Colour analysis gave the results shown to the left (Figure 12) which include the Colour Rendering Index (CRI Ra) and Corrected Colour Temperature (CCT) for each lamp.

These have a reasonable colour rendering index for most colours except strong red (as indicated by CRI R9) – which is largely absent from the spectrum. The overall colour temperature is around 4,000 – 4,500K which is a “warmer” tone than mid-day sunlight, but much more sun-like than a halogen or tungsten lamp.

A Chromaticity Chart was also plotted for each lamp. (Figures 13a-c, below.) Chromaticity coordinates for the lamps are shown as a navy circle; the arc represents the Planckian locus (the chromaticity coordinates of a perfect ‘black body’ radiator at all temperatures).

Fig. 13a

Fig 13b

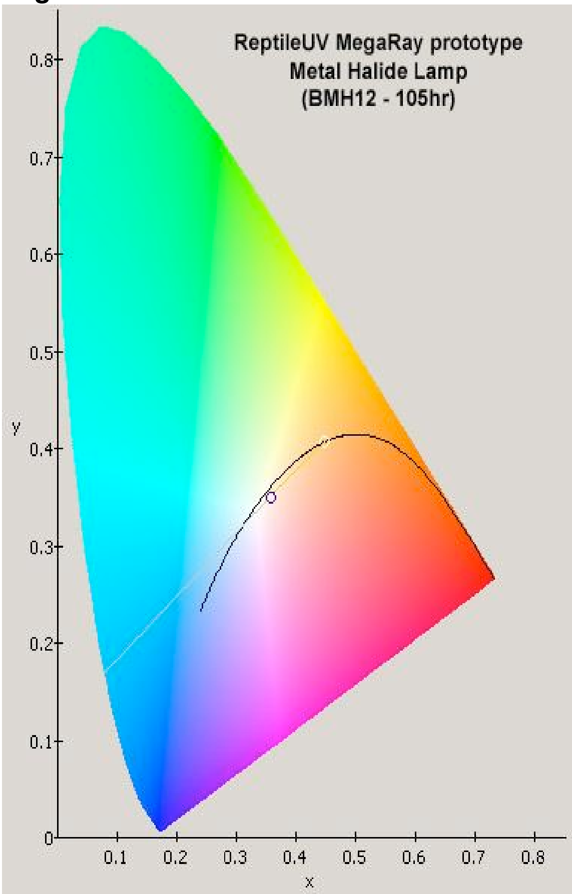
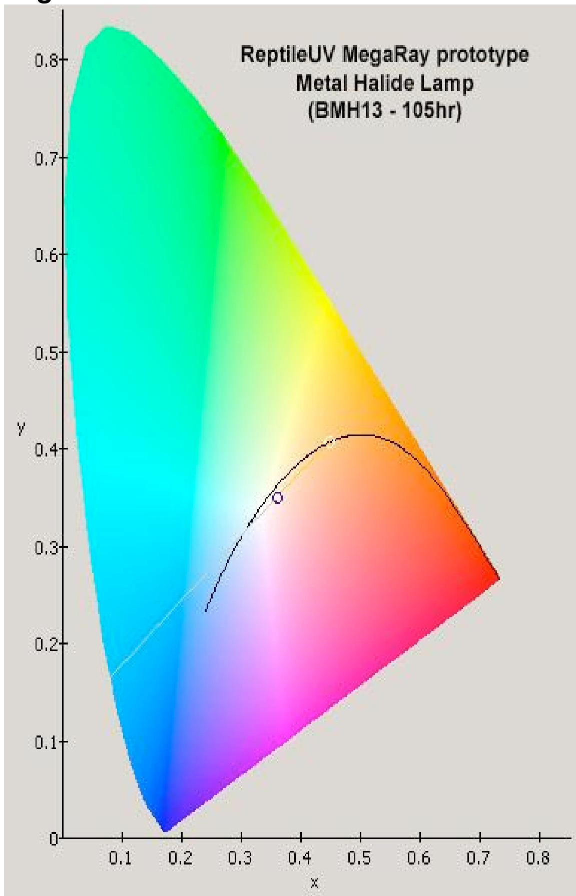


Fig 13c

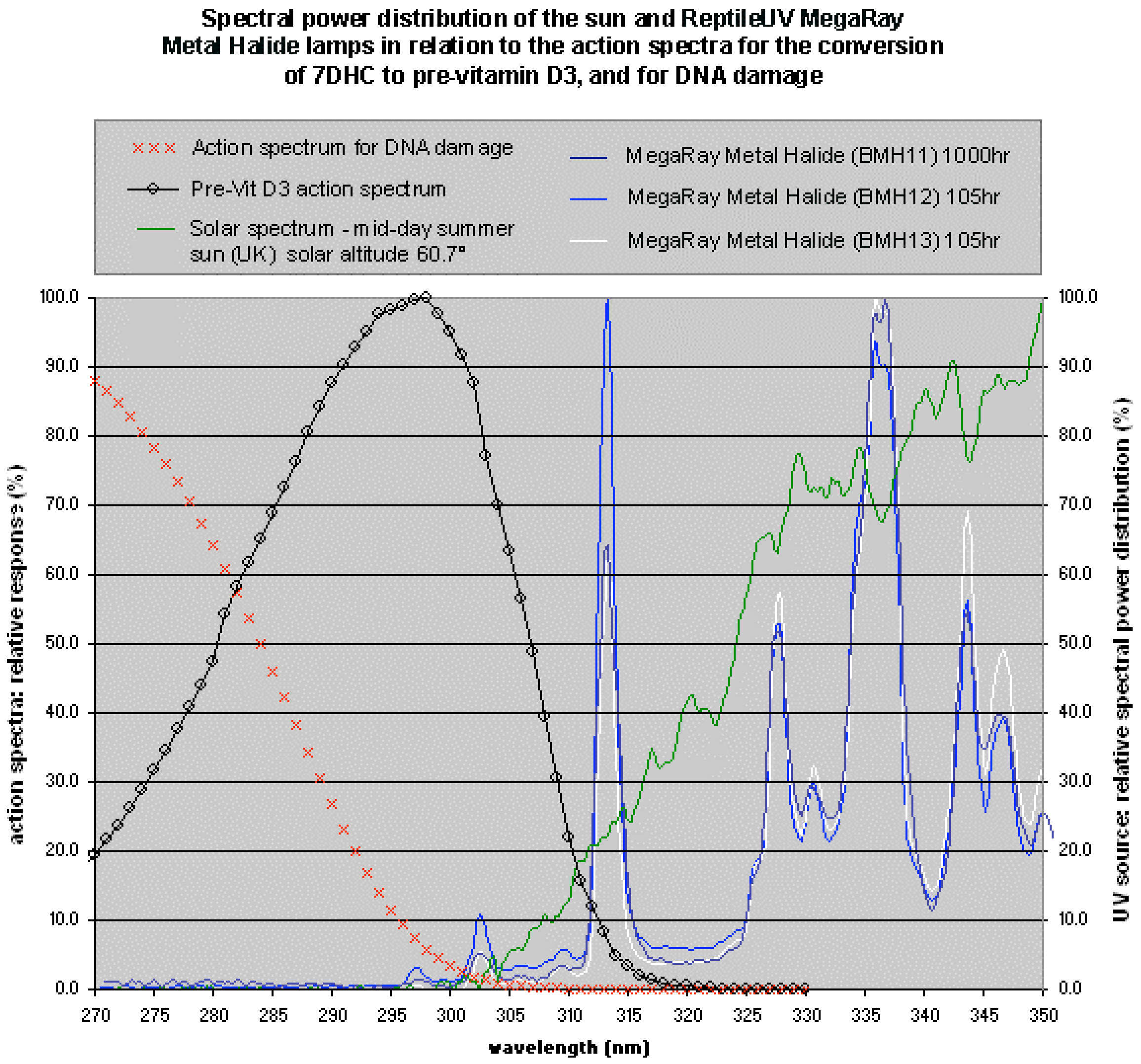


<u>The Relative Spectral Power Distribution of UV light from the lamp</u>

Figure 14 (below) shows the relative spectral power distribution of the sun and the lamps (with the peak irradiance between 270nm and 350nm scaled to 100%, to enable comparison.). Overlaid are the Pre-Vitamin D3 Action Spectrum (CIE 174:2006) and an action spectrum for DNA damage (adapted from Setlow 1974). The extent to which each UV spectrum falls under each action spectrum determines the risks and benefits.

The solar spectrum, as one would expect for a natural system, is virtually perfectly balanced to minimise risk (very little falls under the curve for DNA damage) whilst maximising benefit (a reasonable amount is within the vitamin D3 action spectrum).

Fig. 14



This analysis of the spectra of the metal halide lamps reveals the reason for the higher photo-reactivity than sunlight which is suggested by the meter readings – below 310nm, a higher proportion is in the lower, more photo-reactive wavelengths. However, the threshold wavelengths are similar to those of natural sunlight and hence the risks of cell damage (and also photo-kerato-conjunctivitis) appear to be similar to those seen with exposure to natural sunlight.

This is not to say that extremely bright light and high levels of UVB are harmless, of course. Looking at the sun can cause blindness. Because of the intensity of the radiation (both visible and in the UV range) these lamps, like all basking lamps, should always be positioned **directly above a basking spot**. The shape of a reptile's head, the orientation of the eyes and the upper eyelids (when present) are designed to shade the eyes very effectively from a sun in the sky overhead. Brilliant illumination from the side is un-natural and it is not unreasonable to assume that the visual glare would be a source of extreme stress. The damaging effect of low wavelength UV light upon the surface of the eye, and higher wavelength UV and blue light upon the retina must also be considered very seriously; **these lamps are actually as bright as the sun, at normal basking distances. It is possible that serious eye damage could occur if a reptile had no option but to look at one of these lamps when basking.** It is also essential to ensure that the reptile is provided with adequate shelter from the heat, and from the visible and ultraviolet light, and can freely move in and out of the UV gradient into complete shade at any time.

Conclusion
These preliminary tests suggest that these lamps are likely to be appropriate for widespread use in suitable vivaria which are large enough to accommodate a 70watt lamp whilst ensuring an adequate temperature and UV gradient. They are likely to be suitable for diurnal species which have a known requirement for bright, full sunlight. They are not likely to be suitable for crepuscular species or shade-dwellers.
The prototypes varied widely in their UVB output; lamps of different UVB intensity would be suitable for different species and habitats, depending upon the desired UVB level at the basking spot.

Advice regarding the safe placement of such extremely intense sources of visible light over a vivarium must be given to all purchasers, in addition to detailed instructions on the safe use of high-output UVB lamps and the necessity for a UV gradient in the vivarium.

No tests were made on the heat output of the lamp, but metal halides do not produce as much heat as regular incandescent lamps of equivalent wattage. It is likely that supplementary heat would be required at the basking spot, for many heliothermic species.

Further tests are needed to monitor the UVB decay during long-term use (which will be necessary to determine a recommended lifespan with adequate UVB output)

Author's note
Thank you for allowing me to evaluate these lamps.

Please note, my tests are not conducted in laboratory-controlled conditions. I do believe this equipment and these methods are producing reliable and repeatable results which have scientific validity, but I would encourage professional testing of all these lamps to confirm my findings.
Individual lamps will vary in their UVB output, depending upon their original specifications and upon their age, the quality of the electrical supply, external temperature and doubtless, other factors. Only three lamps have been tested. To be certain that these are typical of their kind would require a much larger sample to be tested.
Because there will inevitably be differences between individual lamps, the charts for the lamps tested in this report should not be relied upon as an accurate guide to the exact output of all lamps of this type.
Comments in this report reflect my personal opinions only.

18th October 2008
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