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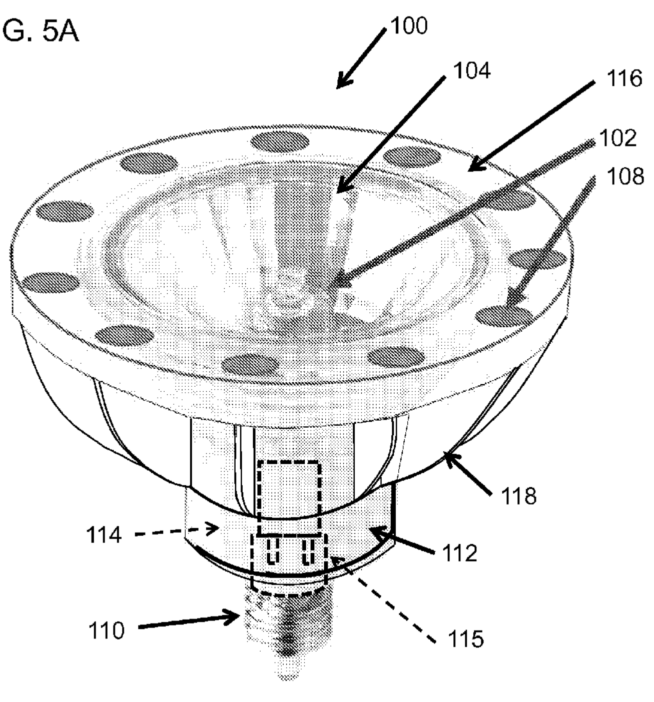
(54) **Title**: OPTIMIZED SPECTRUM REPTILE LAMP

FIG. 5A



(57) **Abstract**: The new lamp, as disclosed herein, is realized by integrating an MR 16 halogen incandescent reflector lamp of appropriate wattage and beam spread in combination with one or more UV LEDs of proper radiant flux in the UVB-UVA spectral range. Since the spectral outputs of the two sources do not significantly overlap, the new lamp is a "platform" with independently adjustable UV and visible-IR spectral distributions and beam patterns, wherein the adjustments are known and predictable.

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OPTIMIZED SPECTRUM REPTILE LAMP

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of US Provisional Patent Application No. 61/908,000, filed 11/22/2013 by Petrak, et al., said application hereby incorporated in its entirety by reference herein.

Note that, as stated in the specification of the incorporated provisional application: *"The drawing pages are informal and may contain annotations including, for example, notes, text labels, and the like.* ***Annotations on the [provisional application] drawing pages should be treated as part of the detailed description or other parts of the specification, as appropriate.****"*

BACKGROUND OF THE INVENTION

Note that the word "light" is used herein to reference radiation (radiant energy) in general, especially any wavelength(s) in the UV to IR range. The modifier "visible" is used for specific reference to the range of wavelengths generally perceivable by the human eye.

It is known that reptiles such as lizards, which are cold blooded, require an external heat source to warm them. In the wild they "bask" in the sun as needed. In captivity, if a suitable amount of sunlight isn't available, then a solution may be to substitute with a "warming light", for example any incandescent lamp will supply more heat than visible light, so it appears to solve two problems - heat is provided along with light for viewing of the reptiles. However, informed reptile keepers know that other parts of sunlight's spectral output are important for the health and well being of reptiles, and studies have shown that the ultraviolet (UV) portion of sunlight is critically important for the health of reptiles (more than for humans). In particular, the UVA range helps general health and wellbeing, and UVB radiation synthesizes vitamin D3 in the skin; however UVC and shorter wavelengths of UVB cause damage to skin tissue resulting in varying amounts of "sunburn" and potentially cancer. Although humans can obtain vitamin D3 from foods like meat, vegetarian reptiles have UV-triggered skin generation as their primary, if not only source.

There have been a lot of trial and error attempts to use existing lamp types that are re-branded and/or adapted for use as reptile lighting products, particularly attempting to add UV. Various kinds of mercury discharge lamps appeared to work better than others in providing both visible light and beneficial UV radiation. This is because the spectral output of a mercury vapor arc discharge (regardless of pressure) includes intensity spikes in UV as well as visible parts of the spectrum. Fig. 1 is a summary chart of the types of lamps that can be used to provide UVB for reptile lighting. They are all mercury discharge lamps. Visible and IR/heat radiation are also output to varying degrees as noted, however none of them is particularly good when compared to natural sunlight.

The Fig. 2 chart compares UV output and resulting vitamin D3 yield for a collection of the reptile lighting products available in 2004 (from research report: *UV Lamps For Terrariums: Their Spectral Characteristics And Efficiency In Promoting Vitamin D3 Synthesis By UVB Irradiation*; by Jukka Lindgren, 2004 (Excerpted from: www.testudo.cc). Sunlight is also shown as a reference, given that it is the natural source of radiation on Earth. The UV measurements are recorded as total UV irradiance and total for each of the commonly defined UV bands (ranges) UVA, B, and C. According to the researcher's report:

"It is concluded that a simple percentage of UVB radiation from the total radiation figure does not necessarily give a true indication of a lamp's capability to maintain cutaneous production of vitamin D3.

"Of all the lamps measured, the best contributor to vitamin D3 photosynthesis in reptile skin is Zoo Med ReptiSun 5.0 UVB, with a D3 Yield Index of 439. This result can be considered especially noteworthy for the fact that the lamp in question is only a 14 W unit, while other units in the study have a nominal power of 30-40 W. The spectrum of ReptiSun begins very low in the UVB range and the spectrum curve rises steeply. In the most sensitive wavelength for vitamin D3 synthesis, 295 nm, for example, the radiation of ReptiSun is already 1.8 times stronger than that of the next best lamp."

This test showed that, while UV in or around the UVB range is a significant predictor of vitamin D3 yield, the spectral power distribution **within** the UV ranges appears to play an important role. For example, the highest D3 yielding lamp had almost the same intensity and percentage of UVB (circled on chart) as a lamp that had about 1/3 the D3 yield.

The reports and the present specification mention the names of many different lamp products. It should be assumed that most if not all of the names shown herein are trademarked in some way; whether or not a TM or R identifier is applied to the names herein the marking and acknowledgement is intended, and should be regarded as if marked appropriately.

Fig. 9 compares typical spectral output power distributions as measured for sunlight, for a halogen incandescent lamp (with a dichroic reflector), and for a mercury vapor lamp named the

REPTILEUV ZOO MEGARAY™ lamp. It may be noticed that neither of these artificial sources mimics sunlight very well across the whole IR to UV spectral range. The incandescent source provides plentiful heat and adequate visible light, but minimal UVA and no radiation in the UVB and UVC wavelength ranges. The dichroic coated reflector can be used to reduce the ratio of heat/IR to visible light intensity (by not reflecting some IR into the beam). On the other hand, the mercury vapor lamp produces copious amounts of UVA, and a fair amount of UVB, but the visible light has a sickly blue-green color, and virtually no IR radiation.

One way to address these deficiencies is by modifying the mercury discharge lamp so that it emits more visible light. This is already being done in fluorescent lamps. They have a (low pressure) mercury vapor arc in a tube that is coated with one or more phosphors that convert UV to longer wavelength radiation, typically in the nearby visible light range. By adjusting the quantity and type(s) of phosphors, a variable amount (intensity) and apparent color of visible light is achieved, and varying amounts of the mercury discharge's UV spikes can be allowed to escape into the beam unconverted, or some being converted to nearby wavelengths to spread it out. A compact fluorescent lamp is a readily available form of a self-ballasted mercury vapor (SBMV) lamp (with phosphor) because it has a ballast incorporated into a shell attached to a medium screw base. Although fluorescent lamps can provide an adjustable amount of visible light with different mixes of wavelengths used to produce different perceived "colors", they still can't provide much IR for warming, and they can't change the UV wavelengths of the underlying major spikes of the low pressure mercury vapor discharge spectrum. One other modification to fluorescent UV lamps is to change the tube to a type of "glass" that will transmit the shorter wavelengths of UV that are heavily absorbed or totally blocked by common glass, but these special materials (e.g., quartz/fused silica) are more expensive and much more difficult to manufacture. Finally, special phosphors have been developed that can convert the mercury lines to a few other UV wavelengths. Changes such as these were implemented in the ZOOMED REPTISUN UVB™ line of compact fluorescent lamps (CFL), and one of them was the best performer in terms of vitamin D3 production among the commercially available reptile lighting products that were tested, as shown in the Fig. 2 chart.

There are a variety of reptile lighting products, all of which include some form of mercury discharge as a source of UV and visible light. Some are called "full spectrum" or "spectrum similar to sunlight" because they provide an appealing color of visible light along with

UVA and a lesser amount of UVB. However, in spite of the "full spectrum" claims, such lamps actually simulate only the visible part of a solar spectrum (using a phosphor mix) and small parts of the UV (generally clustered around the characteristic mercury discharge wavelengths), but virtually none of the IR and longer wavelengths needed to warm a reptile. To obtain a complete reptile "lighting" system, the mercury discharge lamps must be supplemented by a source of heat. For example, the MEGA-RAY ZOO SB™ includes a special warning statement in its catalog description to make sure that a purchaser knows about this problem. (*"Warning: This lamp produces very little heat at a distance of 3 feet. Be sure your reptile is heated properly and if necessary, increase the heat at the basking spot using a good heat source in addition to the UVB lamp."*) Some products attempt to meet this need in a double-socket fixture that combines an incandescent lamp with a CFL. Others have a mercury vapor lamp that combines a high pressure mercury vapor arc tube and an incandescent filament ballast in a single R bulb.

Even though it provides IR, visible and UV radiation, the problems inherent in mercury discharge lamps remain: spectral distribution is a combination of spikes rather than a smooth variation with wavelength, resulting in only small portions of the UV range being emitted; the lighting in the visible range is unnatural, and color varies during warmup and over time of use; the incandescent filament is relatively low power; and the arc tube must cool down before it will restart after being turned off. Or, as stated in a recent article published in *LEDs Magazine*. "... mercury-vapor lamps are hindered by short lifetime (2000-10,000 hr), slow warm-up and cool-down times, and wide spectral power distribution.... In addition, over 60% of the energy that is applied to a typical mercury-vapor lamp is radiated back out as infrared energy, ..and the UV output of a mercury vapor lamp drops off rapidly over its operational life because some of its electrode material vaporizes, depositing a film on the inside of the quartz tube which the UV cannot penetrate. As a result, the user cannot easily predict the amount of UV generated at a later time...". The latter problem can be observed by comparing the output of the two Reptisun lamps, new vs. "used" which had significantly lower output and consequently lower D3 yield.

To date, there are no lamps on the market that are stable over time and that reliably output optimum amounts of heat, light, and UV radiation for reptile lighting. It is an object of this invention to create a light source that corrects such deficiencies.

Along with the wide variety of light sources used for reptile lighting, very little thought has gone into provision of reflectors for directing radiation at desired intensities into a useful size area (e.g., a "basking zone"). For example, "reflector (R)" lamps have their own built-in reflector for beam direction, but R lamps are flood (wide beam) lamps, not spotlights. Most existing reptile lighting fixtures are basically a standard shop clamp reflector with a reflector dome around a screw base socket into which the supplier inserts their own lamp (assuming it has a medium screw base). Reptile lamp suppliers may sell a "premium" fixture in prettied-up packaging and add an adjustable stand for attachment of the reflector. For example, a 160W Self Ballasted Mercury Vapor (SBMV) lamp is sold for reptile lighting under the name EXO TERRA SOLAR-GLO™. Although it is a reflector lamp about 7" diameter it is still placed in a reflector fixture (about 9" diameter) to further concentrate the beam, and possibly also to help limit human eye view of the UV portions of its output. Other reflectors may be used to achieve different beam spreads from different lamps.

However it should be noted that mercury discharge light sources, both low pressure (in fluorescent tubes) and high pressure (e.g., HID arc tubes) are inherently large area emitters which therefor are very difficult to focus into a narrow beam and require correspondingly large fixtures and reflectors to even achieve a broad "floodlight" beam. A compact fluorescent lamp only partly addresses this problem.

For example, a compact fluorescent screw base lamp can be used in an 8.5" aluminum dome to achieve a relatively long and narrow beam, or in a 10.5" white porcelain dome for a relatively wide and short beam (See Figs. 6A-6B).

There are other problems with fluorescent light sources. A normal CFL has a low pressure mercury arc within glass that blocks most of UV, and the phosphor converts UV to visible light in a desired color. The "full spectrum UV" fluorescents use a special phosphor that only converts some UV to visible (making poor visible color) and converts some to a few extra UVB spikes. Using a quartz tube allows UVA and UVB mercury lines to escape through the tube, but also passes damaging UVC radiation. Finally, there is virtually no IR/heat output as indicated by the "cool burning" euphemism in advertisements. A "deep dome" vertical reflector, or a horizontal trough reflector in a hood are needed to focus the spread-out long length of fluorescent light sources.

Thus it is a further object of this invention to be able to retrofit our new light source into the best existing fixtures, but more preferably to provide a compact, self-contained system as a lamp having its own reflector that is optimized for desirable beam patterns without needing an extra reflector.

BRIEF SUMMARY OF THE INVENTION

In view of the above, the Applicants have created an improved Reptile Lighting product having a spectral output distribution that includes optimum amounts (intensities) of radiation in all three desirable wavelength bands: IR for warming, visible (with good color rendering) for human viewing of the reptiles (and for their own eyesight), and UV for vitamin D3 production. As a further objective, we intend to determine and provide the particular wavelengths and relative intensities of UV radiation that are optimum for the health of the reptiles. As we learned, UVA is also beneficial for general health and wellbeing of a reptile.

This definition of lamp design objectives may be inventive in its own right, along with the novel means we employ to achieve the objectives. In particular, given all the problems inherent in using mercury discharge light sources, the applicants decided to use a different and better source of UV, and combined it with the best source of visible and IR/heat radiation.

As will be seen from the description hereinbelow, a result of research conducted during the design phase, coupled with new design possibilities enabled by our new lamp concept prompted us to form additional design objectives that enhanced the new product in ways never before possible. As a result, the hereindisclosed lighting product has become a market changing major innovation rather than simply an incremental improvement.

The invention has been improved by the applicants' determination of what constitutes "optimum amounts" of radiation in the three wavelength bands that are important to reptiles: UV, IR, and Visible. In ongoing research and development work we are refining our specifications for the optimum wavelengths or sub-bands and corresponding optimum intensities to be as precise as possible where needed. For example, the intensities of specific UV wavelengths are more important to know than the spectral intensity distribution for wavelengths of light in the visible and IR ranges, because vision and warming are rather broadband effects (the same overall effect may be produced by an average of many different intensity-versus-wavelength distributions).

BRIEF DESCRIPTION OF THE DRAWINGS

Reference will be made in detail to preferred embodiments of the invention, examples of which are illustrated in the accompanying drawing figures. The figures are intended to be illustrative, not limiting. Although the invention is generally described in the context of these preferred embodiments, it should be understood that it is not intended to limit the spirit and scope of the invention to these particular embodiments.

Certain elements in selected ones of the drawings may be illustrated not-to-scale, for illustrative clarity. The cross-sectional views, if any, presented herein may be in the form of "slices", or "near-sighted" cross-sectional views, omitting certain background lines which would otherwise be visible in a true cross-sectional view, for illustrative clarity.

Elements of the figures can be numbered such that similar (including identical) elements may be referred to with similar numbers in a single drawing. For example, each of a plurality of elements collectively referred to as 199 may be referred to individually as 199a, 199b, 199c, etc. Or, related but modified elements may have the same number but are distinguished by primes. For example, 109, 109', and 109" are three different versions of an element 109 which are similar or related in some way but are separately referenced for the purpose of describing modifications to the parent element (109). Such relationships, if any, between similar elements in the same or different figures will become apparent throughout the specification, including, if applicable, in the claims and abstract.

The structure, operation, and advantages of the present preferred embodiment of the invention will become further apparent upon consideration of the following description taken in conjunction with the accompanying drawings, wherein:

Figure 1 is .... , according to the invention.

Figure 5C is a perspective view of a lamp in normal BU burning position showing a lamp structure that provides for LED mounting and cooling , according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

Drawing Reference Number Key

Ref. No.	**Term definition**
100	Optimized spectrum reptile lamp
102	incandescent light source (e.g., halogen filament tube, preferably low V to make it short)
104	reflector for the incandescent light source (e.g., MR16 reflector, which is aluminized and/or dichroic coated.) pref adapted to provide a design beam spread (e.g., 40 degrees)
106	incandescent source component (combination of inc light source mounted in its reflector) e.g., MR16 lamp

108	UV LEDs (light emitting diodes that emit ultraviolet radiation) 108a, 108b, etc. = UV LEDs with different output specs and/or physical forms
110	base of lamp
112	body of lamp (optionally includes a bi-pin or other type of plug jack for both electrical and mechanical connection of MR16 to the base).
113	open frame LED mounting structure
114	power control circuitry - preferably contained in the body and base
115	internal socket for MR16 bi-pin plug base, to removably connect MR16 to medium screw base
116	LED mounting plane
118	heat sink structure **heat sinking structure**, (such as convection cooling fins oriented to be vertical when the lamp is used in a specified burning orientation such as Base Up>)
120	**UV beam control apparatus -** - control, shaping, concentration, direction or redirection of the UV LED radiant output to form it as a beam
120a	**lens and/or reflector optics applied to each LED.** This may be supplied as a preassembled LED package (e.g., the TO-39 cylindrical can style).
120b	secondary reflector (applied to LEDs as a group) - may also help further shape the incandescent lamp radiant output beam
122	UV beam
124	visible + IR beam
Method:	radiant output power and spectral distribution in the beam is adjusted by variations in incandescent lamp power, voltage, color temperature, and other filament tube variations according to known design methodology (e.g., fill gas pressure, halogen chemistry, and the like), wherein the variations are set to a baseline by design and are further variable by the user by means such as supply voltage variation.

	Radiant output power and spectral distribution in the beam is also adjusted by variations in reflector size, shape, and reflective characteristics of the reflector, which may be dichroic coated and may be adapted to achieve a ratio of reflection to transmission that varies with wavelength in a predetermined way, thereby setting a design radiant power spectral distribution (e.g., wavelength varying reflectivity adjusted to a design ratio of IR to visible radiation, and/or to optimize the CRI). A partly transmissive reflector will be accommodated by suitable openings in the lamp body to prevent excessive heat buildup.

A novel means for achieving an optimized spectrum reptile lamp according to our objectives was conceived and developed as follows.

Structural Design Elements and Considerations

An MR16 halogen incandescent lamp 106 (example in Fig. 4A) is utilized as an incandescent light source 102 for providing visible and IR radiant energy. It has a halogen filament tube permanently fixed in a reflector 104, and generally uses a low voltage (12V) filament to minimize the light source length. Advantageously, the MR16 lamps are a well established family of stable, and relatively more efficient incandescent lamp designs that can be modified in several ways to optimize both the heat and the visible light outputs. Also its relatively small (2" diameter) integral reflector 104 should help provide a narrow focused beam more like a spotlight than a flood. The 12 volt, 10,000 hr models of MR16 lamps 106 are considered the ideal candidate. Various wattages and reflector variations are available for achieving different beam spreads and variation in spectral power distributions at different mounting heights. The MR16 lamps 106 enhance reptile appearance due to their high CRI.

The desired UV radiation is provided by adding a plurality of UV LEDs 108 (light emitting diodes, e.g., Fig. 4B) to the MR16, attaching them to a structure that also holds the MR16.

The result is a novel "lighting platform" upon which we can "build" a family of lighting products starting with Reptile Lamps. For starters, the family will include variations in output power and possibly also variations in the UV spectral power distribution and/or relative power of the IR/heat vs. visible lighting vs. UV.

Example reptile lamp embodiments 100 that utilize this platform are shown in the concept sketches of Figs. 5A, 5B, 5C. Notes:

- Body structure/shell 112 built around MR16 lamp 106.
- The lamp body 112 contains power control circuitry 114 as needed to drive and regulate both the incandescent lamp 106 and the UV LEDs 108.
- MR16 lamp plugs into a bi-pin socket 115 wired to medium base 110.
- Optionally a 12V-to-120V converter is included in the body. (Alternative: use a 120V Halogen lamp filament tube in the MR reflector 104.)
- An LED Heat Sink structure 118 may be added as needed.
- body contains whatever is needed to interface the reptile lamp 100 with a standard AC line voltage (e.g., 120VAC) supplied by a standard socket for the standard base 110.

Fig. 5B shows a first example UV beam control apparatus 120 wherein a reflector 120b is formed around the ring of LEDs 108, for example attached to the LED mounting plane 116.

Fig. 5C shows a second example UV beam control apparatus 120 wherein a reflector 120a is integrally formed around each LED 108. Alternatively the UV beam control 120a may be refractive lens optics applied to each LED, or both combined. These control options may be provided built into the LED, as in a TO-39 cylindrical can (Fig. 4B).

Fig. 5C further illustrates another embodiment of LED mounting and cooling wherein an open frame structure 113 supports cooling fins 118 integrated with individual LED mounting pads. Open construction (e.g., wire frame) allows good airflow for cooling the LEDs, and also exposes the back of the MR reflector 104 to allow cooling of it, and/or to allow radiation transmitted through the reflector (e.g., excess IR if a dichroic reflector is used) to escape behind (above) the lamp body 112 rather than accumulating in it.

Design considerations:

- The body contains all necessary circuitry for operating the LEDs and the halogen lamp together as a single light source.
- Additional structure may be provided to control the beam shape, especially for the LEDs, (see Figs. 5B, 5C) which may have any combination of reflective and refractive optics such as, but not limited to, a reflector/shield at least partly around each LED, a reflector encircling the ring of LEDs, a lens on each LED, and the like.
- Cooling fins or other types of heat sinks 118 may be provided to limit the LED junction temperature, for example like LED "light bulbs" now being sold. (see Figs. 5A, 5C)

- The MR16 reflector 104 may be aluminized for total reflection, or specially coated (e.g., dichroic) to control the relative amount of IR in the beam, and/or to prevent overheating of the LEDs.
- The MR16 lamp 106 can be unplugged and pulled out of the lamp body 112 for replacement when it burns out, because the LEDs have a much longer expected useful life (e.g., 70,000 hrs.)
- The LEDs 108 are selected to provide the intensity levels and specific UV wavelengths that are determined to be optimum according to the invention (as disclosed hereinbelow).

In summary, the invention combines two light source types to make a single lamp having a unique spectral output that is optimized for reptile* lighting = Halogen Incandescent + UV LEDs. (*in this embodiment). In an embodiment, a 50W, 75W, or 100W MR16 aluminum reflector halogen incandescent lamp 106 is combined in a single lamp structure 100 with a plurality of high power, narrow wavelength range UV LEDs 108. The LEDs are selected for emitting the UV wavelength range(s) specified according to the invention, and the quantity of LEDs is defined as needed to obtain the UV flux total(s) specified according to the invention.

Baseline for the Lamp Design

As a baseline for performance comparison, one of the better prior art examples of a 120V reptile lamp was selected: the ZOO MED™ 100W SBMV (Self Ballasted Mercury Vapor) lamp. This is entirely self contained, having a high pressure mercury arc UV source, an internal ballast that also serves as an incandescent source of visible and IR, plus a built-in reflector (R bulb) and a universally usable medium screw base for a 120V socket. (The high pressure mercury arc tube also contributes IR as a hot body, plus some visible light spiking at characteristic wavelengths of violet, violet-blue, green, and yellow.)

Our design process was divided into two tasks, broadly stated as:

A. Matching or improving the Visible and IR spectral power distribution of the baseline SBMV lamp. (However, recognizing that radiant heating may be caused by radiation at almost any wavelengths, not just IR, what we actually seek to "meet or beat" are the effective **visual lighting** and **radiant heating** outputs of the complete lamp.)

B. Improving on the UV spectral power distribution of the baseline SBMV lamp. (What we are really after is the **best effects of the UV**, i.e., optimum vitamin D3 production and overall health and wellbeing of the reptiles, including minimizing any potential negative effects related to the wavelength and intensity of the radiation.)

DESIGN TASK A: VISIBLE AND IR SPECTRAL POWER DISTRIBUTION

The spectral power (flux) distribution for a Zoo Med 120V 100W SBMV lamp was measured over the 350 - 1050 nm visible-IR range, resulting in the graph of Fig. 3. As expected, the spiked output of the high pressure mercury vapor arc tube shows as additions on top of the smoothly varying incandescent filament radiation which peaks in the IR as determined by the temperature of the hot filament.

Obviously we don't want to precisely duplicate the measured spectral power distribution. In practical terms, what we actually seek to "meet or beat" is the visual lighting and the radiant heating effects of the lamp on a reptile basking in its beam. For comparison purposes, we will assume that our new lamp will have an equal or better beam pattern and percent of total radiant output that will effectively "hit" a basking reptile. This means we can compare total "light" and "heat" outputs.

We used the total radiant flux (W) over the measured range as a measurement of the lamp's maximum ability to radiantly heat a basking reptile = 12.94 W (watts) or 11.84 W from the incandescent filament ballast only (integrating under the smooth curve and ignoring the spikes).

The total lumens is a measurement of the lamp's maximum ability to visually light a basking reptile (and whatever else is in the lighted area of the beam pattern) = 802.6 lm.

Based on these numbers, we selected a 12V 50W MR16 Aluminum Reflector Lamp as a likely equivalent. The spectral power distribution measurement supported our choice. The total radiant power is 11.42 W and the total visible light is 849 lumens. These are a reasonably close match, with 6% more illumination (lumens) and slightly less (-4%) heating capabilities. These differences may be made insignificant by improvements to things like the reflector that should improve the beam pattern uniformity and focus/concentration.

The measurements show significant benefits due to qualitative improvements introduced by changing to our new lamp. We have much better CRI (99 vs. 69) and a huge (250%) increase in lighting efficacy from 6.7 to 16.7 LPW. We also have a very significant energy savings with lamp input power cut from 119W to only 51W. Of course the power demand will increase when we add LEDs to supply the UV, but certainly not as much as 68W!

Our tests showed that the purely incandescent MR16 is operating at a more efficient, higher filament temperature with peak output moved from IR to visible and even contributes a bit to UVA between 350-400 nm. (see a similar lamp's output in Fig. 9). It also shows how the mercury lines distort the SBMV visual effect by adding color casts and wasting energy with the high narrow spikes in the visible range.

These results show that the MR16 lamp family is a good candidate to replace the SBMV lamp in the extended visible and IR regions of 350 to 1050 nm.

Fig. 6A shows how the 50W MR16 can be used to satisfy the performance specs typical for rainforest reptile species and/or small area-short distance reptile basking and lighting.

Example specs for lower UV requirements:

- UVB: 30 µW/cm2 Maximum Intensity
- Visible/IR: 11.4 W total Radiant Flux

Selected Halogen Lamp: 50 Watt MR16

Fig. 6B shows how switching to available higher wattage MR16 halogen incandescent lamps can likely meet higher output requirements typical for desert reptile species and/or large area-long distance reptile basking and lighting.

Example specs for higher UV requirements:

- UVB: 150 µW/cm^2 Maximum Intensity
- Visible/IR: (to be determined)

Available Halogen Lamps: 75 or 100 Watt MR16

In both cases, we will use a broad beam spread (e.g., 40 degrees) for the visible-IR and a narrow beam spread (e.g., 15 degrees) for the UV. An advantage of our design is that our use of separate optics for UV enables us to focus most of the UV radiation in the basking zone, while the visible and IR are spread out for general lighting and warmth.

In conclusion, these test results indicate that the overall design concept will provide many performance benefits, plus flexibility in design variation including:

- Visible/IR vs. UV radiant power levels are separately adjustable in design, and ratio-adjustable by a user if we enable some type of rheostat adjustment of incandescent power.
- Visible/IR-only operation (UV shut off) at user's discretion
- Modular design allows replacement of the shorter-life MR16 while the LEDs continue in use.

- Several beam spreads are possible giving customer a choice of irradiance levels and beam spread (using different wattage halogen filament tubes and/or different reflector sizes and arrangements.

DESIGN TASK B. LED SPECIFICATIONS

In general, Applicants have determined that optimum UV radiation distributions can be attained by adding currently available UV LEDs to our novel lighting platform as described hereinabove with reference to some embodiments illustrated in Figs. 5A-5C. Our platform/design concept will accommodate a combination of different center-wavelength LEDs to allow precise "tuning" of the UV spectral power distribution, and will also enable scaling the total UV power and/or adjusting relative intensities at different UV wavelengths, by changing to higher power LEDs and/or by changing the number of LEDs that output selected UV wavelengths. Details are provided hereinbelow after we describe our design/development process.

As a result of Applicants' research, we redefined our task to the following: Determine the optimum UV spectral power distribution (UV-SPD) for reptiles, then utilize the fine tuning possibilities and the latest UV LED technology to design a market changing, greatly improved reptile lamp.

Determination Of "Optimum Amounts" Of UV Radiation

In order to specify the LEDs, research was required, which led us to a more sophisticated specification than that implied by the prior art assumption that "UVB is good for reptiles" (due to vitamin D3 production). So we want to determine what is the "best" UV spectral power distribution (UV-SPD) relative to overall reptile health, and secondly how should the UV-SPD and/or the full spectrum Power Distribution change relative to location in the lamp beam pattern and in the full reptile living area?

Beam Pattern and Basking Zone

Addressing the second part of the design task first, we refer to the known concept that UVB is needed in a "basking zone" of limited area so that the reptiles can move in and out of it as needed to regulate their exposure time - too much exposure time can have negative effects. For example, consider the following recommendations for:

UVB INTENSITIES IN A BASKING ZONE*

Sun Worshippers: 300 μW/cm2 max (75 - 150 preferred range)

Rainforest species: 30 μW/cm2 max (15 – 30 preferred range)

UV Index: <10 (indicates amount of damaging UVB < 300 nm)

*Basking Zone: Area of given UVB intensities at a specified distance directly under the source after stabilization.

Figs. 7A-7B show how the same lamp (a ZooMed Reptisun 10.0 CFL™) will produce very different beam patterns when used in two different reflectors. Conclusion: reflector shape determines basking zone distance and size. Here we see very different size basking zones depending upon the reflector and distance. The source for these measurement plots noted that the aluminum reflector in Fig. 7A provides approximately the same "beam pattern" (intensity distribution versus location) for the UV as for the visible due to fairly constant reflectivity, but the porcelain dome in Fig. 7B has virtually zero reflectivity for UVB radiation versus fairly good reflectivity in the visible range.

Problem with Aluminum Reflector: This means that with an aluminum reflector, the prior art all-in-one light sources will either under-light the majority of the enclosure, or else will light everything except for a "hiding spot" that must be created so that the reptile can self-regulate its UVB exposure by getting out of the UVB radiation. Unfortunately this means that the reptile cannot be seen except when it is basking.

Problem with Porcelain Reflector: The situation is even *worse* for the porcelain reflector, because *the UVB will have a wider spread than the visible light*.

The only way for prior art reptile lighting to avoid the above dilemma is to use more than one light source.

Advantage of our New Design: Returning now to Figs. 6A and 6B we see that our design concept can provide a single lamp solution, by using separate optics for UV. This enables us to focus most of the UV radiation in a concentrated basking zone (e.g., 15 degree beam spread), while the visible and IR are spread out for general lighting and warmth (e.g., 40 degrees spread).

Fig. 8 shows another example of problems with the prior art reptile lighting - in this case a narrow focused "UVB" reflector lamp (i.e., not much IR output) sold as a MEGA-RAY ZOOLOGIST PAR38 60W 120V™. It has been designed to be "A High Output, Long Range Lamp for Reptiles Needing High UVB Exposure in Large (High Ceiling) Enclosures". An independent tester, F. Baines, took the measurements plotted in Fig. 8 in 2004 for the marketing website having URL www.ReptileUV.com. In his report Baines stated:

"The Basking Zone at 3' (36") distance is about 10" in diameter to receive 100 - 250 uW/cm² of UVB. the beam widens sufficiently to provide what would seem to be a most useful area within which a basking reptile can receive high levels of UVB, as if basking in a patch of natural sunlight. For example, at a distance of six feet from the lamp, the area within which a reptile may receive a useful but natural level of UVB radiation, is a large circle approximately 30 inches across. (20 uW/cm² at its edge, to just over 100 uW/cm² at its centre.)" "The minimum distance at which the lamp should be used is 30" where I recorded a maximum of about 360 - 380 uW/cm². This is equivalent to the UVB readings I have seen given for mid-day sunshine in several parts of the world including the Australian outback, the Cayman Islands and Tenerife, and so it might be considered within the normal basking range for some species of sun-loving lizards, for example. At distances closer than 30", it produced extremely high levels of UVB radiation – for example, directly under the lamp at 12" distance, levels of UVB radiation exceed 1,500 uW/cm². Care must be taken to exclude animals or humans from the hazardous levels of UVB radiation at such close range."

So we see the potentially serious negative health effects that can come with improper use of UV emitting devices. Further reading of the same report reveals some of the other problems inherent in the prior art reptile lighting in general. Baines observed:

"Many UVB-emitting lamps demonstrate a rapid period of decay in UVB output (often described as "burning-in") over the first few days of use, followed by a slower decline in output over subsequent months....

"The lamp performed like other Mega-Ray mercury vapor lamps I have tested, in that when first switched on, it produced a faint light which developed over a few minutes into a very bright light with (to the human eye) a purplish-blue tint. As with all mercury vapor lights I have tested so far, the readings "danced" at close range, and in fact the visible light can often be seen to "dance" as well, casting flickering shadows at the edge of the beam. Presumably this is a normal artifact due to the way the radiation is generated....

"Individual lamps will vary in their UVB output, depending upon their original specifications (Mega-Rays, for example, are all calibrated individually as they leave the manufacturer) and upon their age, the condition of the ballast, the quality of the electrical supply and doubtless, other factors....

"When taking readings for spread charts, I have found that mercury vapor lamps do not produce a perfectly symmetrical beam. This is presumably due to the off-centre positioning of some of the elements inside the lamp plus minor eccentricities in the shape of the glass envelope, the orientation of the lamp in its socket, and so forth. This lamp, for example, has a beam which "wobbles" slightly to the left."

We also note asymmetry in the plot: Max intensity “center of beam cone” is off-axis. This points out another disadvantage of mercury vapor arc tube sources of UV that attempt to position a large arc tube at the focal axis of the reflector bulb.

Two significant measurement distances are pointed out: 30 inches and 36 inches. According to the report "the minimum distance at which the lamp should be used is 30" .... At distances closer than 30", it produced extremely high levels of UVB radiation – Care must be taken to exclude animals or humans from the hazardous levels of UVB radiation at such close range.... The Basking Zone at 3' (36") distance is about 10" in diameter to receive 100 - 250 uW/cm² of UVB."

Considerations Regarding the "Amount" of UV

There has been a gradual development of knowledge about UV effects related to UV wavelengths. At first, the thinking was, the more UV the better. Then as shown in Fig. 2, the vitamin D3 yield was linked mostly to UVB (280-320 nm) rather than UVA, but measured with meters that only read the total intensity for all wavelengths in the UVB band (280-320 nm). Quoting from the UV Guide UK website (www.uvguide.co.uk):

"Manufacturers usually describe, for each product, the percentage of the total light output of the tube which is emitted as ultraviolet light. Hence a lamp may be described as producing "30% UVA and 5% UVB" and this would mean that the remaining 65% of output was emitted as visible light [and IR]. This gives an indication of the balance between UVA, UVB and visible/IR light but it does not indicate the intensity of ultraviolet illumination which can be expected; i.e., it does not distinguish between a dim, inefficient lamp and a bright, efficient one.

"Our broadband UVB meters measure something different: the total UVB output in microwatts per square centimeter - the actual intensity of UVB illumination. ...

"A higher reading does not necessarily indicate that the tube is better at promoting synthesis of vitamin D3. Different brands [with different phosphor blends and/or glass tubes, and therefore different proportions of UVB at various wavelengths] may have similar overall UVB

output but vary in their ability to promote vitamin D3 synthesis. ..

"Different lamps vary enormously in the amount of UV light they emit, and in the type of beam they produce. If two lamps produce, for example, 20uW/cm² of UVB at 12" distance, but one lamp has a beam that is twice as wide as another, then a large reptile sitting 12" away, which cannot sit completely inside the beam, will be able to produce more D3 from the lamp with the wider beam...

"It's also very useful to know how much the output of a lamp decays with time. Good UVB lamps are expensive, because of the quality glass, phosphors, arc tubes and so forth that go into their production, and because many mercury vapor lamps are actually handmade."

So we see that D3 yield depends upon the actual wavelengths, even within the UVB band. Viewing Fig. 9, we see the "action spectrum of 7-DHC to PreD3 conversion" according to a 1982 study. This peaks at around 295 nm and spreads from about 250 nm to about 315 nm (and some of the mercury spectral lines happen to fall in this range). In view of this it was thought that (but later proving to be inaccurate):

a) UVA doesn't help,

b) more UVB would be better,

b) providing shorter wavelength UVB (at, or below 300 nm) would get more bang for the buck by hitting the conversion peak.

This thinking led Lindgren, the author of the 2004 study summarized in Fig. 2, to identify two "Subranges":

- UVB-1 = 280 - 304 nm = Which he thought was "best for Vit. D3 production" and
- UVB-2 = 305 - 319 nm = Thought to have negative effect on Vitamin D3 production (at time of study, 2004)

According to another source, the subrange of 290 - 300 nm is labeled "D-UV" meaning that it's considered the best range for Vitamin D3 production (since it surrounds the peak conversion).

Lindgren also reported: *"Of all the lamps measured, the best contributor to vitamin D3 photosynthesis in reptile skin is Zoo Med ReptiSun, with a D3 Yield Index of 439. This result can be considered especially noteworthy for the fact that the lamp in question is only a 14 W unit, while other units in the study have a nominal power of 30-40 W. The spectrum of ReptiSun begins very low in the UVB range and the spectrum curve rises steeply. In the most sensitive wavelength for vitamin D3 synthesis, 295 nm, for example, the radiation of ReptiSun is already*

1.8 times stronger than that of the next best lamp."

The ReptiSun lamp in 2004 was a new design using a different "glass" for the fluorescent lamp arc tubing that allowed shorter wavelength UVB to pass through, plus phosphors that boosted and spread out emission in the UVB wavelength range.

UV Wavelength Limitations

Unfortunately, the 2004 work failed to account for problems that might arise due to the use of radiation that isn't present in the natural earth environment. Fig. 11A is a simplified version of the Fig. 9 plot showing the Pre-Vitamin D3 (Pre-D3) Action Spectrum and the Solar spectrum in the UV bands. Although there is much more UV in outer space (vacuum) our atmosphere protects us by absorbing radiation roughly in inverse proportion to the radiation wavelength. So the longer the wavelength is, the less of it is absorbed - thus the rising curve. Secondly, the less atmosphere that the radiation passes through, the less it is attenuated. The solar angle (or altitude) indicates this. When the sun is directly overhead (90 degrees) we not only receive the "brightest, hottest" sunlight, but we also get the greatest amount of UV exposure in general, plus lower wavelengths reach effective intensities. In essence, the solar SPD curve moves toward shorter wavelengths. The Solar spectrum in Fig. 11A is only at about 61 degrees elevation even though it is at noon in the summer without clouds, because it is in a northern latitude. The plot shows barely any radiation below about 303 nm. Under the same conditions in the tropics, the sun will get much closer to 90 degrees, and the "natural" amount of UV in full sun exposure is much greater and extends at effective levels down to shorter wavelengths in the "low UVB" range. Finally, the lowest end of the solar plot is partly determined by the amount of Ozone in the air, because air attenuates radiation wavelengths with decreasing effectiveness up to about 200 nm. Ozone, however, is more reactive and effectively attenuates wavelengths up into the UVB range above 280 nm. This is fortunate, because the cell-damaging effects of higher energy (shorter wavelength) radiation extend all the way up to the upper UVB wavelengths as shown by the x-marked curve in Fig. 11A. Given this we can see that although lower UVB might be more effective in Pre-D3 conversion, we may want to do like the sunlight and just use the upper part of the Pre-D3 curve, which peaks at about 295 - 297 nm.

This conclusion is supported by a 2007 study by Baines (UV Guide UK) of severe eye irritation in reptiles exposed to some, but not all of the higher intensity "UVB" lamps developed as a result of Lindgren's 2004 study. The "best performing" Reptisun CFL lamp was among those that caused problems. Baines measured the UV spectral distribution of many available reptile lamps and reported as follows [figures re-numbered herein]:

[As seen at the top of Fig. 11A:] *"The black curve* [o-marked] *is the Pre-Vitamin D3 Action Spectrum (CIE 174:2006) (4), which shows the potential of a given wavelength to enable vitamin D3 synthesis. As can be seen, this* ***overlaps with the solar spectrum*** [solid line] ***up to about 315 - 320nm.*** *Wavelengths at around 298nm (where the action spectrum peaks) are most efficient, but the amounts of this in sunlight are very small indeed. Higher wavelengths are progressively less efficient, until* ***wavelengths above about 315nm*** *can be seen to have very little effect indeed. Having said that,* ***there is vastly more light at these higher wavelengths, so their effect may be just as important as the tiny but more potent amounts at around 300nm.***

"The red curve [x-marked] *is an* ***action spectrum for DNA damage*** *(adapted from Setlow 1974). This shows the* ***potential of a given wavelength to cause injury and death to cells.*** *From this graph, it can be seen that* ***the lowest wavelengths of sunlight, around 300 - 310nm, do overlap this action spectrum.... no strong sunlight is perfectly "safe" as we know... but most of the solar UV spectrum lies outside of this "danger zone".***

[The lower part of Fig. 11A] *"...shows the UV spectra of a small selection of* ***reptile UVB lamps which have not been associated with ...health problems.*** *... All have a similar* ***threshold wavelength around 290 - 295nm, followed by a steady rise up towards UVA. The shape of the spectra is similar to that of sunlight up to about 340nm,*** *but then* [because it's a mercury discharge lamp] *the UV output falls again and there is very little higher wavelength UVA except for the mercury emission peak at 365nm.*

[Fig. 11B shows] *"...spectra of the fluorescent lamps which have been connected in some way with cases of photo-kerato-conjunctivitis. All of these appear to utilize a very* ***different phosphor, which is generating low wavelength UVB from a threshold as low as 275 - 280 nm.***

"It is tempting to assume that all that is necessary, to enable these lamps to be used safely, is to calculate "safe" minimum basking distances with what seems to be ***a suitable UV Index,*** *and ensure that these are always used. Although this approach should reduce the irradiation to a level where photo-kerato-conjunctivitis is unlikely, it may not be a long-term solution.*

"It is important to remember that the UV light which is producing these high UV Indices contains non-solar wavelengths. The effect of non-solar radiation on living cells is

different to that of sunlight*. Even using the UV Index as a guide for a safe basking distance may not be appropriate with these wavelengths in the beam."*

Regarding the "UV Index", Baines further comments:

"Broadband UVB meters, such as the Solarmeter 6.2, measure the entire UVB range (280 – 320nm) and give a readout of the total UVB irradiance in μW/cm². They 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 lamp with "stronger" UV light could be misleading as regards the potential of the lamp to cause cell damage, photo- kerato-conjunctivitis, or, for that matter, to enable the synthesis of vitamin D3.

"We therefore needed to find out how much of the UVB from these lamps was 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 done by measuring the UV Index (UVI) of light from the lamp at various distances.

"The UV Index is a universal, unitless measure indicating the intensity of UVB radiation in the biologically active range of wavelengths - specifically, the wavelengths that enable skin synthesis of vitamin D3, cause damage to the DNA of living cells, and produce erythema (sunburn) in human skin. It is widely used in assessment of solar radiation -and even announced on weather forecasts.

"We have just begun to use the Solarmeter 6.5 UV Index Meter to reveal the "photobiological activity" of different lamps. This meter gives a direct readout of the UV Index. In simple terms, the meter "weights" the readings from different wavelengths, giving a "higher score" to the more biologically active wavelengths. The final, total "score" is the UV Index."

In general, it has been determined that a maximum UVI in the UK latitudes is about 9, versus 10-14 in the tropical and desert regions where solar elevation approaches 90 degrees. Levels above 17 are not found on earth. The index can therefor be used as a soft limit, and is shown in Figures 10A-C where a limit of UVI = 10 is suggested. Nevertheless, the UVI still only indicates an average effect over a range of damaging UV wavelengths. Unlike mercury discharge lamps, our new design allows us to establish a firm cutoff limit to avoid almost all damaging UV - for instance we design to minimize radiation below about 303 nm, and our UV-SPD is tailored to steeply decrease to zero as we approach the lower UVB wavelengths, pretty much the same as the solar radiation on Earth. This kind of control cannot be achieved with mercury discharge radiation where intensity spikes must be dealt with - for example, the most intense output for low P mercury vapor arc is at 253.7 nm in the UVC range.

Optimizing UV for Reptile Health

Now that we have established some boundary conditions, we take a closer look at the details of cutaneous Vitamin D3 production. Excerpts from a 2005 report on "Sunlight and Vitamin D" (www.uvguide.co.uk/vitdpathway.htm) tell the story with reference to Fig. 10:

*"**Vitamin D & Ultraviolet Light – UVB Synthesis:** The pathway begins when a cholesterol, provitamin D (7-dehydrocholesterol, or 7DHC), is manufactured by cells in the skin. When exposed to UVB at wavelengths between 290 - 315nm, this provitamin D, held within the cell membrane, is converted very rapidly to previtamin D3. The peak production is at 297nm.*

"Previtamin D3 is then isomerised (transformed by a re-arrangement of atoms in the molecule) slowly, in warm skin, over several hours, to vitamin D3. Warmth is needed for the reaction to proceed at a normal rate. Reptiles obtain this heat from the sun, as they bask.

*"**The Regulation of Vitamin D3 Production – Equilibrium under UVB/UBA**: Hyper-vitaminosis-D is not known to occur in basking reptiles (or any other species) obtaining their vitamin D from sunlight, regardless of how long they bask. This is because there are inbuilt safety mechanisms preventing overproduction of vitamin D in the skin. Interestingly, these also rely upon ultraviolet light.*

"When a reptile basks in full sunlight, previtamin D3 is produced very rapidly and accumulates in the skin. Its conversion to vitamin D3 is a much slower, heat dependent process. One might expect huge quantities of preD3 to build up, but this does not happen. This is because preD3 is also sensitive to ultraviolet light up to 325nm; a proportion is converted quite rapidly into two biologically inactive products, lumisterol3 and tachysterol3. These also accumulate in the skin.

"Under ultraviolet light, an equilibrium forms with varying concentrations of the three, depending in part upon the exact wavelengths of the light. The three substances have slightly different action spectra. Lumisterol3 may be converted back to preD3 by light of wavelengths up to 315nm; tachysterol3 responds right up to 335nm, which is in the UVA range.

*"**Behavioral Regulation of UVB Exposure**: Some reptiles may be able to sense whether or not they need vitamin D and alter the time they spend basking under UVB light accordingly.*

In one study, panther chameleons (Furcifer pardalis) fed a diet low in vitamin D3 spent more time basking under ultraviolet light than those on a high D3 diet. In addition, they were more attracted to lamps emitting UVB than to equally bright lamps which emitted UVA."

The UV optimization process of the present invention is summarized in Fig. 10, where we see how several different wavelength spreads in the UVB and UVA ranges drive four processes. If we add the boundary condition of minimizing radiation below 303 nm, then we see that all of the processes benefit from UVB up to 315 nm, that up-conversion to Lumisterol3 and Tachysterol3 (L3 and T3), plus down-conversion of T3 exclusively benefit from 315 - 325 nm radiation and down-conversion of T3 also benefits from radiation in the 325 - 335 nm range.

Our novel lamp concept enables a variety of ways to tailor the UV output in accordance with our research findings. As illustrated and partly described in Fig. 12A, a first embodiment of our UV-LED design method uses LEDs having peak outputs such as the following: a primary peak (highest intensity) is at 305 nm (nanometers) with a narrow distribution of about ± 3 nm, thereby leaking only very small amounts of UV below 303 nm. The three secondary peaks are all about 2/3 the magnitude of the primary, and have ± 5 nm distributions around peaks at 310, 320, and 330 nm, respectively.

As illustrated and partly described in Fig. 12B, a second embodiment of our design method utilizes broader output range LEDs which overlap above 303 nm to form a combined SPD (not shown) that rises steeply from 303 nm to a peak/plateau around 315 nm, then tapers back down from about 325 - 340 nm.

Of course what we do depends upon what is available, affordable, and stable and so on. Sourcing of suitable LEDs has begun. We have identified several vendors of UV LEDs having suitable power levels at appropriate wavelengths. A particularly good looking vendor is *Sensor Electronic Technology, Inc. (SETI)* (http://www.s-et.com/uvtop.html). It looks like we can purchase what we need from them. In particular, their UVTOP310 chip (310 nm peak output) looks like it will cover most of the range that we want if it is truly as broad as claimed. The 320nm chip would cover the rest. It is available with a flat window for Lambertian emission and a hemispherical lens or reflector for collimated/more focused emission (TO39 package only).

Summary - These are unexpectedly broad, so probably can just use 310 and 320 models shown here. -- Also use TO39 for focus

Although the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character - it being understood that the embodiments shown and described have been selected as representative examples including presently preferred embodiments plus others indicative of the nature of changes and modifications that come within the spirit of the invention(s) being disclosed and within the scope of invention(s) as claimed in this and any other applications that incorporate relevant portions of the present disclosure for support of those claims. Undoubtedly, other "variations" based on the teachings set forth herein will occur to one having ordinary skill in the art to which the present invention most nearly pertains, and such variations are intended to be within the scope of the present disclosure and of any claims to invention supported by said disclosure.

CLAIMS

What is claimed is:

1. A lamp emitting radiant energy having a spectral distribution that is optimized for reptiles, the lamp characterized by:

a unitary combination of:

an **incandescent light source** mounted in a **reflector**;

one or more **UV LEDs**, being light emitting diodes that emit ultraviolet radiation; and

a **base** for providing mechanical support and electrical connection to a line voltage source.

2. The lamp of claim 1, wherein:

the base is a medium screw base or equivalent.

3. The lamp of claim 1, further characterized by:

a **body** that holds **power control circuitry** and **heat sink structure** for driving and regulating the incandescent light source and the LEDs.

4. The lamp of claim 1, further characterized by:

the incandescent light source and its reflector being combined as an **incandescent source component** that is removably held by the body; and

the body provides supporting and electrical connection between the base and the incandescent source component.

5. The lamp of claim 4, further characterized by:

the incandescent source component being an MR16 type of visible and infrared (IR) radiation source, having a high pressure halogen filament tube affixed at the focus of a reflector.

6. The lamp of claim 1, wherein:

the UV LEDs are mounted on the reflector, and are provided with a **heat sinking structure**.

7. The lamp of claim 1, further characterized by:

a plurality of UV LEDs having a plurality of very narrow spectral distributions centered on different UV wavelength peaks selected to optimize different parts of the vitamin D3 production process in reptiles.

8. The lamp of claim 1, further characterized by:

at least two UV LED types selected for having overlapping spectral distributions and intensity levels suitable for optimizing vitamin D3 production by producing an optimum combined radiation intensity profile over the vitamin D3 producing spectrum from 295-335 nm.

9. The lamp of claim 1, further characterized by:

UV beam control that is achieved by **lens and/or reflector optics applied to each LED.**

10. The lamp of claim 1, further characterized by:

an **LED mounting plane** surrounding the forward end of the incandescent light source reflector;

a ring of LEDs on the LED mounting plane; and

a **secondary reflector** attached to surround the ring of LEDs and extend forward therefrom;

thereby providing b**eam control and shaping** for the UV and optionally for the visible + IR radiant output.

11. The lamp of claim 1, further characterized by:

a visible+IR beam spread of 40 degrees; and

a UV beam spread of 15 degrees.

12. The lamp of claim 1, further characterized by:

a design optimized for rainforest species reptiles, producing a relatively narrow beam of UVB radiation with 30 microwatt per square cm maximum intensity; and

a relatively broad beam with about 11.4 watts of total radiant flux in the visible and IR range.

13. The lamp of claim 1, further characterized by:

a design optimized for desert species reptiles, producing a relatively narrow beam of UVB radiation with 150 microwatt per square cm maximum intensity; and

a relatively broad beam of radiant flux in the visible and IR range.

14. A method for providing a source of radiant energy having a spectral distribution that is optimized for reptiles, the method characterized by:

making a unitary combination of:

an **incandescent light source** mounted in a **reflector**;

one or more **UV LEDs**, being light emitting diodes that emit ultraviolet radiation; and

a **base** for providing mechanical support and electrical connection to a line voltage source.

15. The method of claim 14, further characterized by:

utilizing the LEDs to provide a UV spectral power distribution (SPD) that is adjustable independently of the visible-IR SPD.

16. The method of claim 14, further characterized by:

selecting LEDs to provide optimum intensities of the specific UV wavelengths that are most helpful to the process of synthesizing vitamin D3 in reptiles while also balancing overall health benefits versus risks associated with specific UV wavelengths.

17. The method of claim 16, further characterized by:

minimizing UV below 303 nm to avoid skin cell damage, eye irritation and other such negative health effects.

18. The method of claim 14, further characterized by:

utilizing a plurality of UV LED types having very narrow spectral distributions, which enables us to fine tune the UV spectral distribution to maximize vitamin D3 production by using different center wavelength LEDs to provide optimum intensities of the different UV wavelengths that are most helpful to each different part of the vitamin D3 production process.

19. The method of claim 14, further characterized by:

utilizing two UV LED types having overlapping ranges broad enough to achieve a suitable intensity profile over the entire vitamin D3 producing spectrum (from 295-335 nm).

20. The method of claim 14, further characterized by:

separately controlling beam spread and intensity pattern shaping for the UV radiation versus the visible + IR radiation by the use of independent optical components, thereby enabling wide area lighting and heating simultaneously with UV focused into a smaller basking zone.

FIG. 1 ***PRIOR ART*** THE MAIN TYPES OF LAMP USED TO SUPPLY UVB IN A VIVARIUM

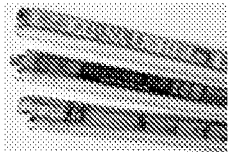
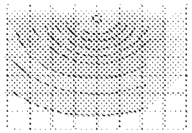
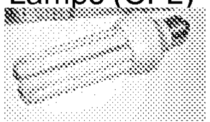
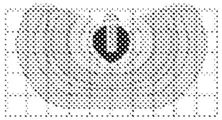
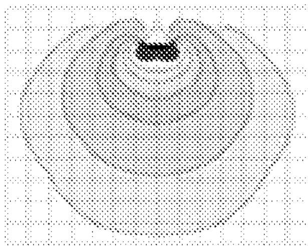
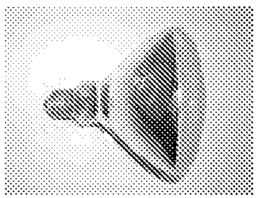
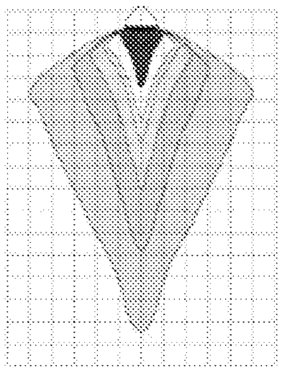
TYPE	BEAM	DESCRIPTION
UV Fluorescent tubes 		Tubes supply a diffuse “glow” with low intensity visible light, little heat, and a fairly uniform UVB gradient, over a relatively large area, resembling natural UVB “in the shade” on a sunny day. Needs a reflector to concentrate output in a smaller area.
UV Compact Fluorescent Lamps (CFL) 		Compacts provide a more intense UVB gradient concentrated in a smaller area, but still provide only fairly low intensity visible light and little heat. Concentrate more by adding a reflector.
Mercury Vapor Floods (Reflector (R) Bulb, Self-Ballasted) 		Compared to fluorescent lamps by themselves, true “flood” lamps produce a more intense UVB gradient concentrated in a smaller area because they have a built-in reflector. The source is an arc tube* with a more intense arc than fluorescents, and it produces more intense visible light plus some heat, but is still more of a diffuse “glow” than a concentrated beam. Poor color rendition.
Mercury Vapor Spot and Narrow Flood Lamps (Externally Ballasted and Self-Ballasted) 		Also uses an arc tube source*. Typically has clear lens on R or PAR reflector bulbs that produce a better focused beam. Very bright light and high UVB concentrated like a patch of sunlight. Self ballasted versions use an incandescent filament as ballast, and therefor produce more heat and an even more intense visible light. -- * Note: There is great variation in spectral distribution for mercury vapor arc tubes, especially depending upon fill gas pressure and use of added chemicals – both of which enhance the spectrum compared to the few narrow spikes output by a low P mercury arc tube.

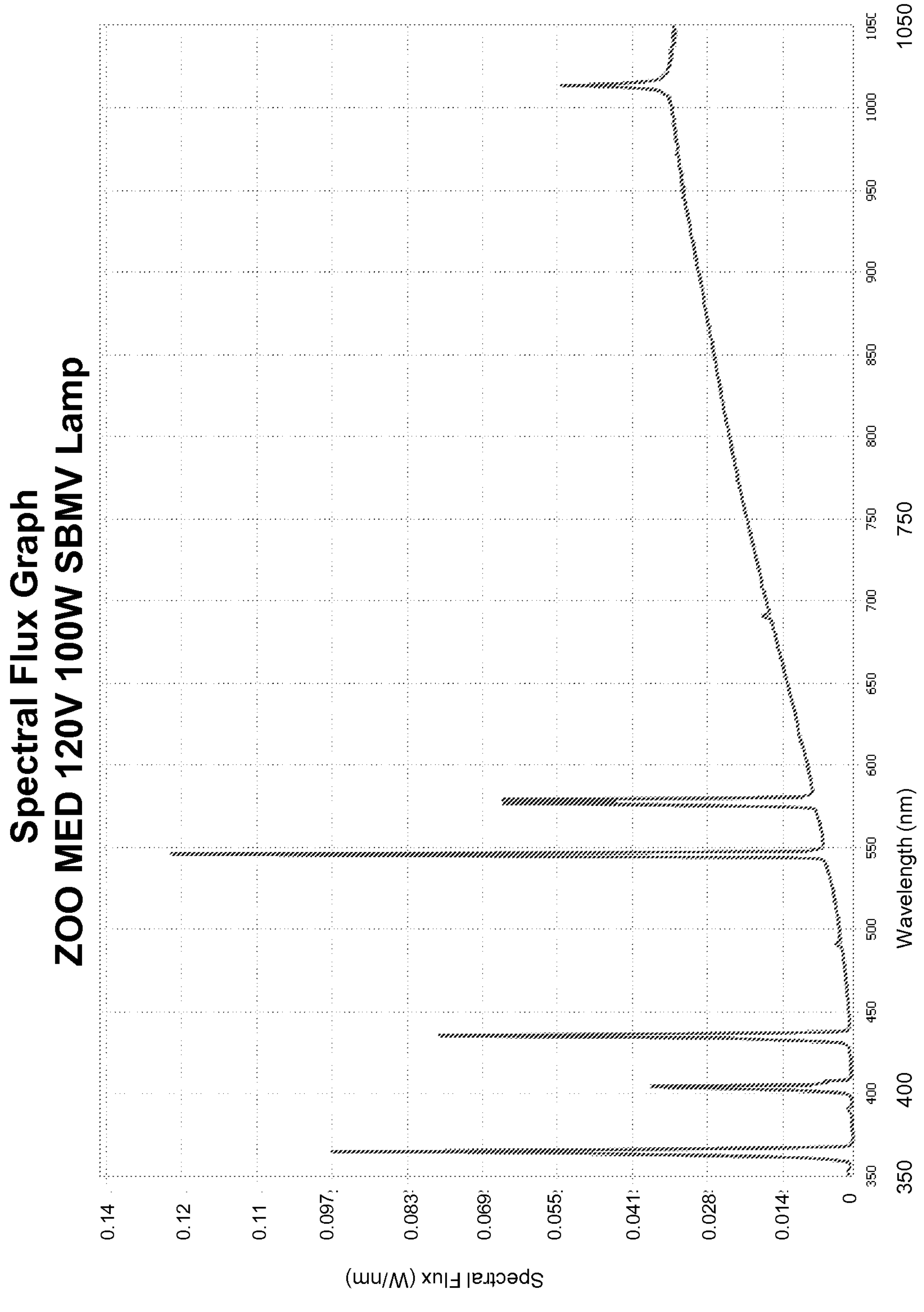
FIG. 2
PRIOR ART

UV ranges are defined as:
UVA = 320-399 nm,
UVB = 280-319 nm,
UVC = 250-279 nm

UV Irradiance vs. D3 Yield

Product	D3 Yield Index	Time to 50 J/m² dose		UV Tot.	UVA		UVB		UVC	
		minutes	hours	µW/cm²	µW/cm²	%	µW/cm²	%	µW/cm²	%
Sun	1000,0	11	0,2	3520,5	3402,8	8,1 %	117,7	0,3 %	0,00	0,00 %
ZooMed Reptisun 5.0 UVB	439,3	43	0,7	58,2	47,9	31,9 %	10,3	6,8 %	0,02	0,00 %
ZooMed Reptisun 5.0 UVB (used.)	367,7	52	0,9	48,0	39,6	31,3 %	8,4	6,6 %	0,01	0,00 %
Narva Reptilight	283,7	66	1,1	44,4	37,2	23,2 %	7,1	4,4 %	0,05	0,00 %
Active UVHeat 100W Flood	165,3	79	1,3	311,1	295,7	22,6 %	15,5	1,2 %	0,00	0,00 %
R.C. Hagen Exo-Terra Repti Glo 8.0	190,2	99	1,7	72,7	65,0	35,6 %	7,7	4,2 %	0,00	0,00 %
Sylvania Reptistar	157,5	100	1,7	70,2	58,7	31,2 %	11,5	6,1 %	0,01	0,00 %
R.C. Hagen Exo-Terra Repti Glo 5.0	150,8	129	2,2	38,7	33,4	21,2 %	5,3	3,4 %	0,00	0,00 %
R.C. Hagen Repti-Glo	22,4	780	13,0	4,6	3,5	1,7 %	1,1	0,6 %	0,00	0,00 %
Active UVHeat @ 1.5 m dist.	20,4	781	13,0	18,1	16,9	19,5 %	1,2	1,4 %	0,00	0,00 %
R.C. Hagen Life-Glo	19,5	870	14,5	4,1	3,2	0,9 %	0,9	0,3 %	0,00	0,00 %
ESU Reptile Super UV Daylight	11,2	1339	22,3	7,7	6,6	5,7 %	1,1	1,0 %	0,00	0,00 %
True-Light	9,2	1501	25,0	19,2	18,5	11,9 %	0,7	0,5 %	0,00	0,00 %
ESU Reptile Desert 7% UVB	0,5	2228	37,1	38,3	37,8	26,2 %	0,4	0,3 %	0,00	0,00 %
R.C. Hagen Exo-Terra Repti Glo 2.0	2,2	4417	73,6	1,9	1,4	1,0 %	0,5	0,3 %	0,00	0,00 %
True-Light Daylight 6000	0,0	108216	1803,6	1,8	1,8	1,3 %	0,0	0,0 %	0,00	0,00 %

FIG. 3
(Prior Art)



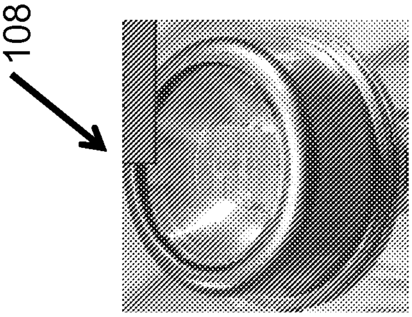


FIG. 4B

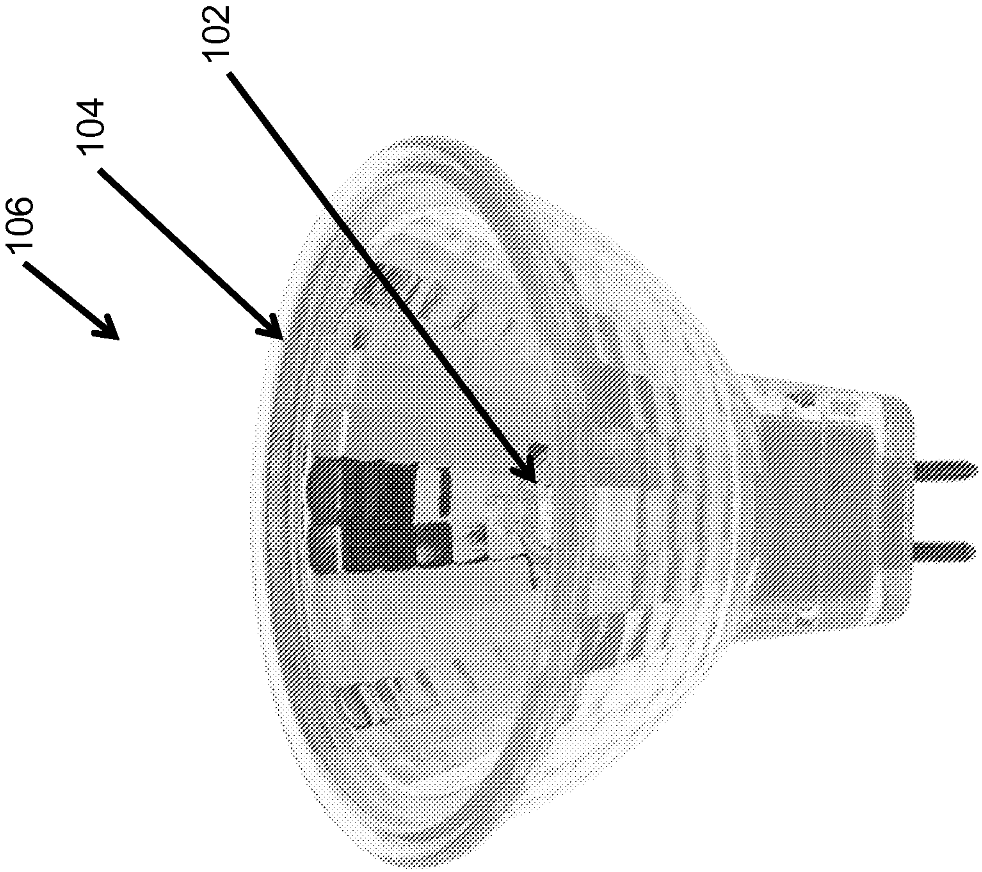


FIG. 4A

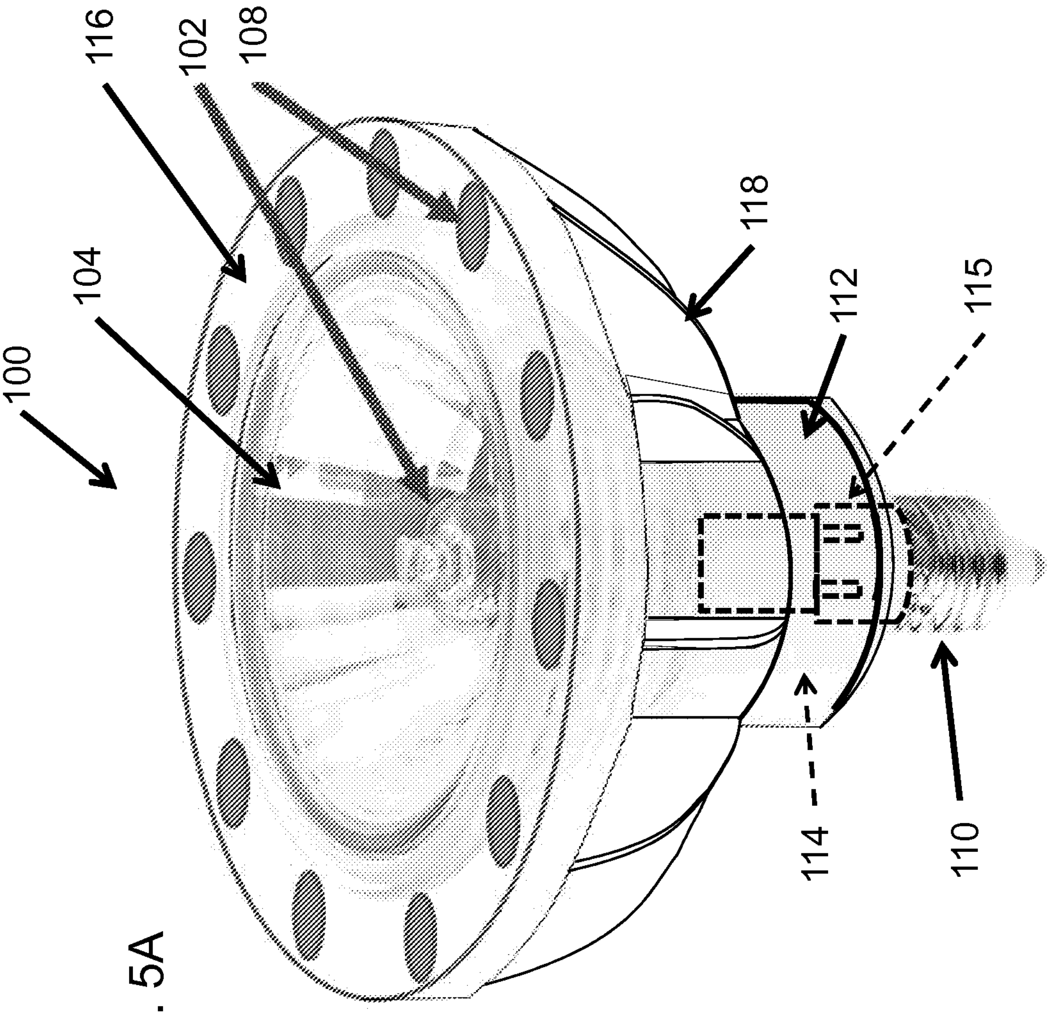


FIG. 5A

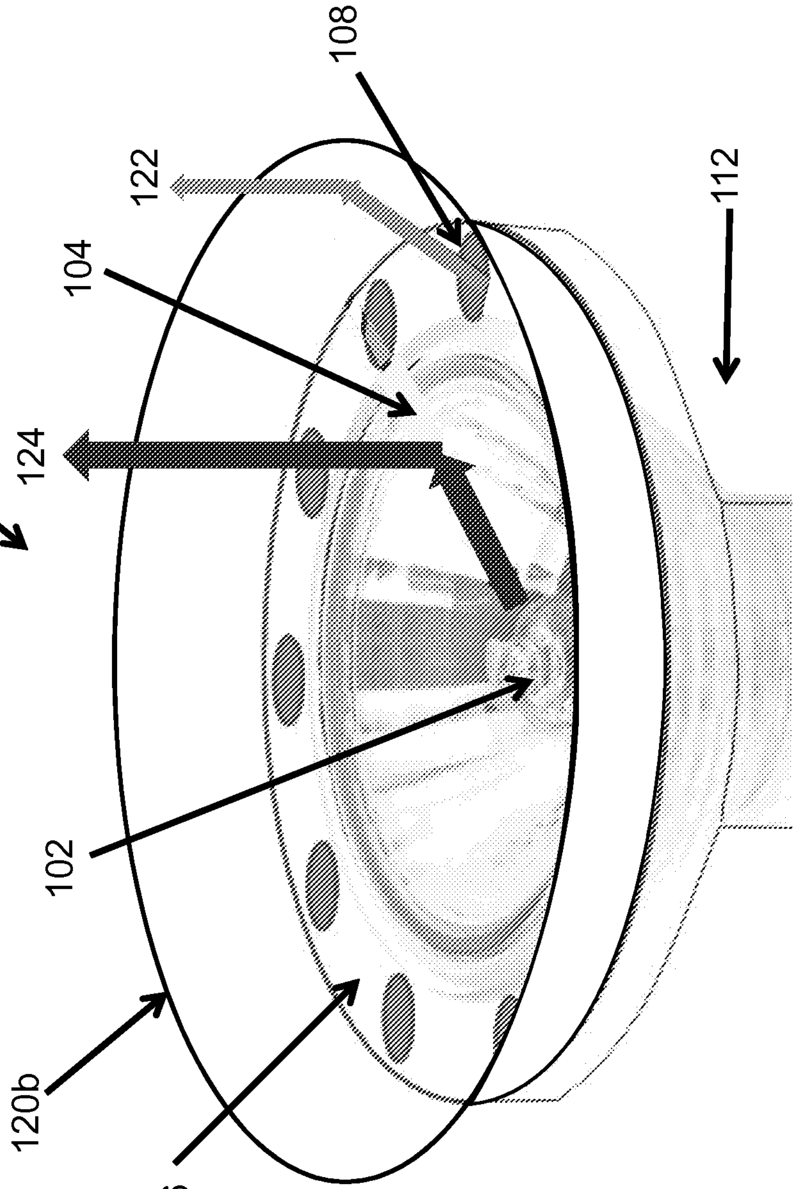


FIG. 5B

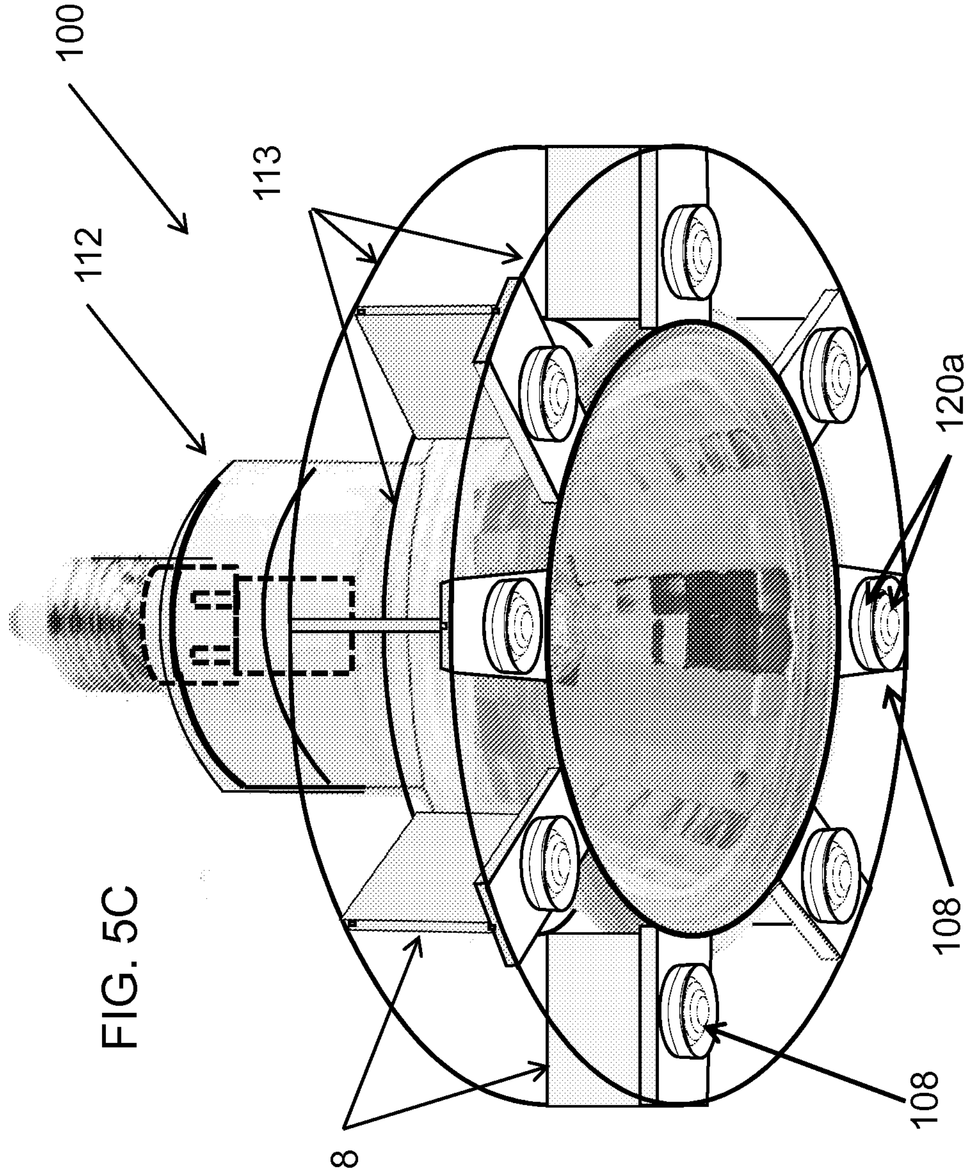
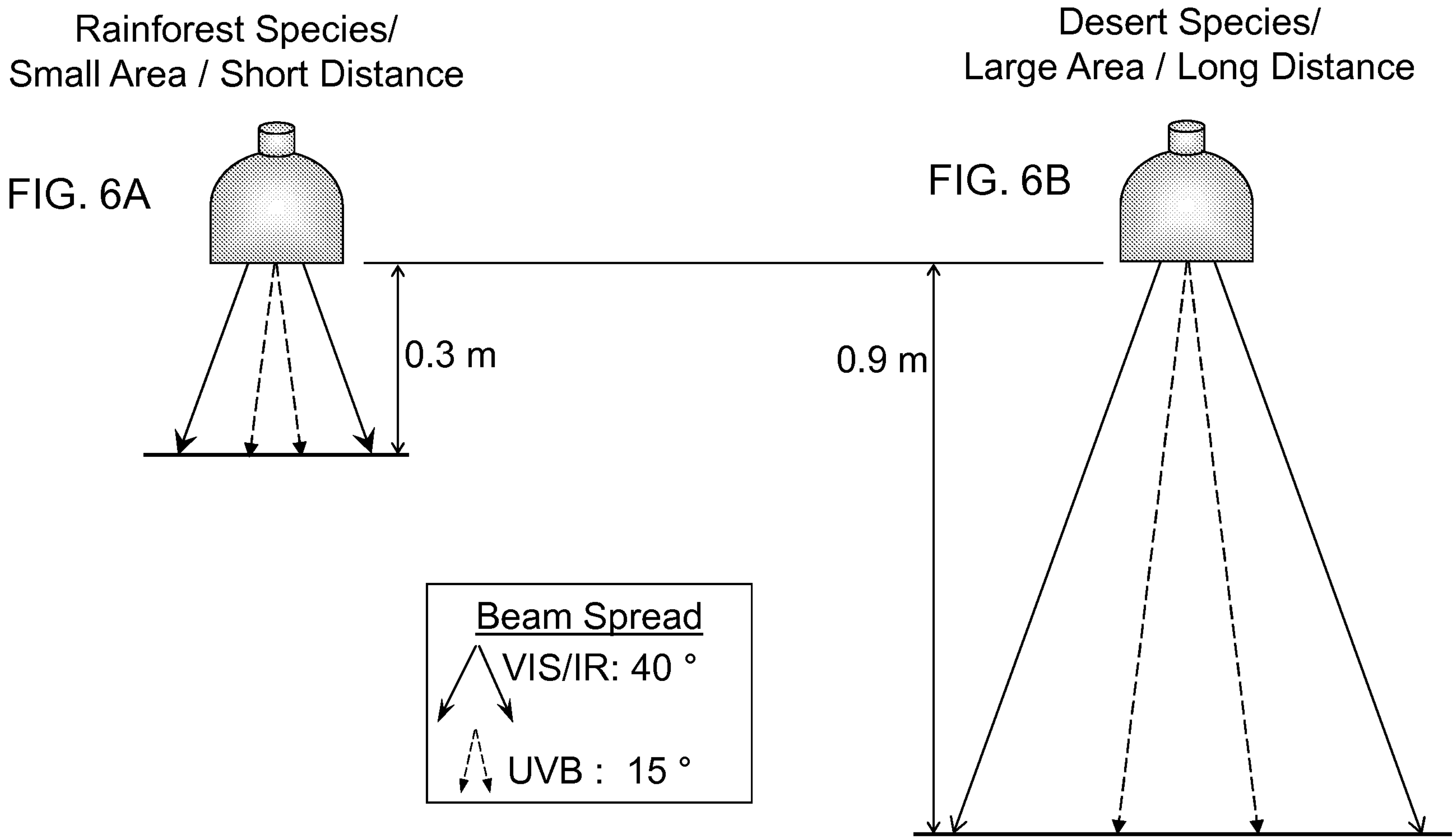


FIG. 5C

FIG. 6A

FIG. 6B


Rainforest Species/
Small Area / Short Distance
0.3 m
Desert Species/
Large Area / Long Distance
0.9 m
Beam Spread
VIS/IR: 40 °
UVB : 15 °

PRIOR ART

FIG. 7A

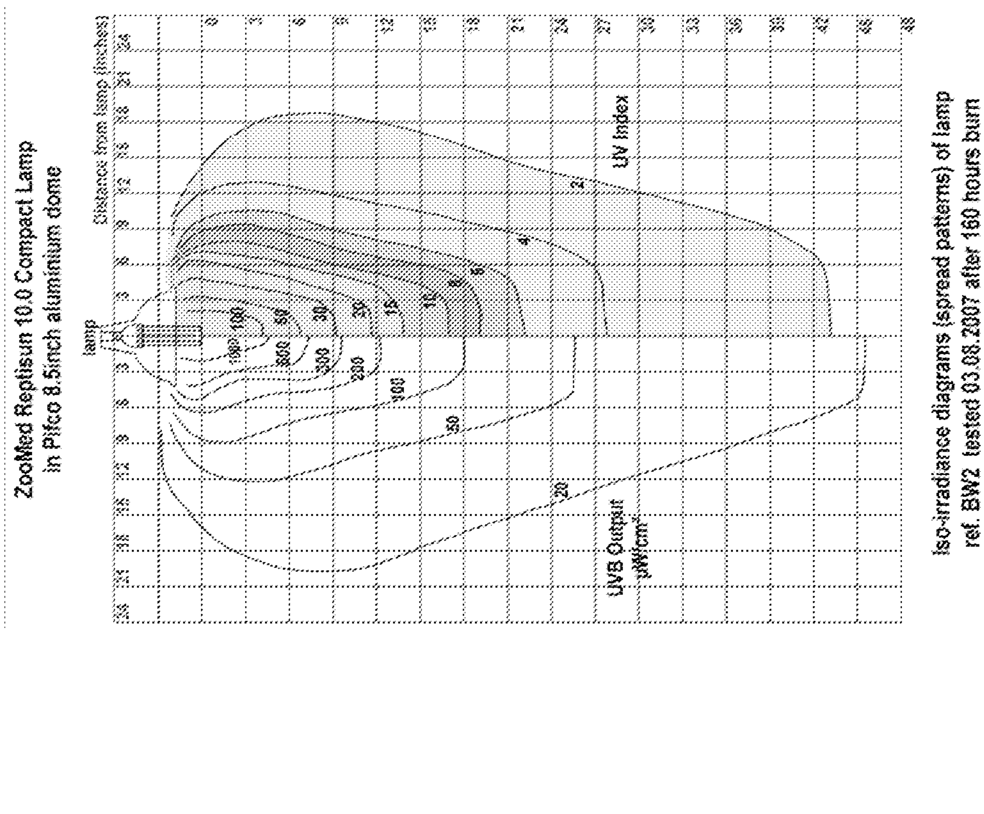
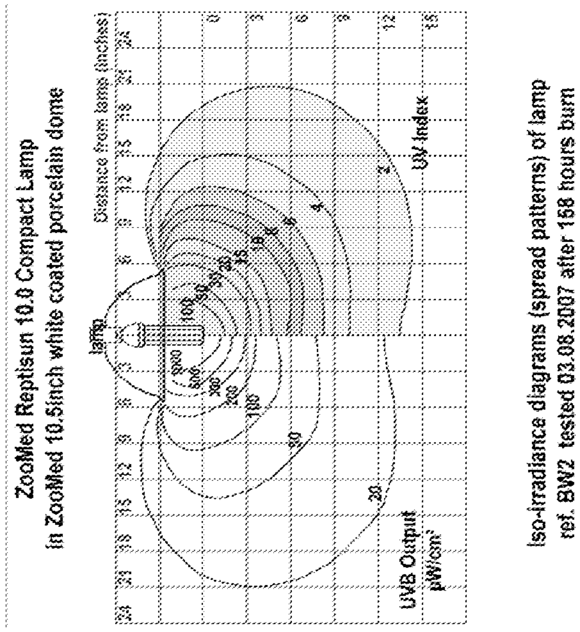


FIG. 7B



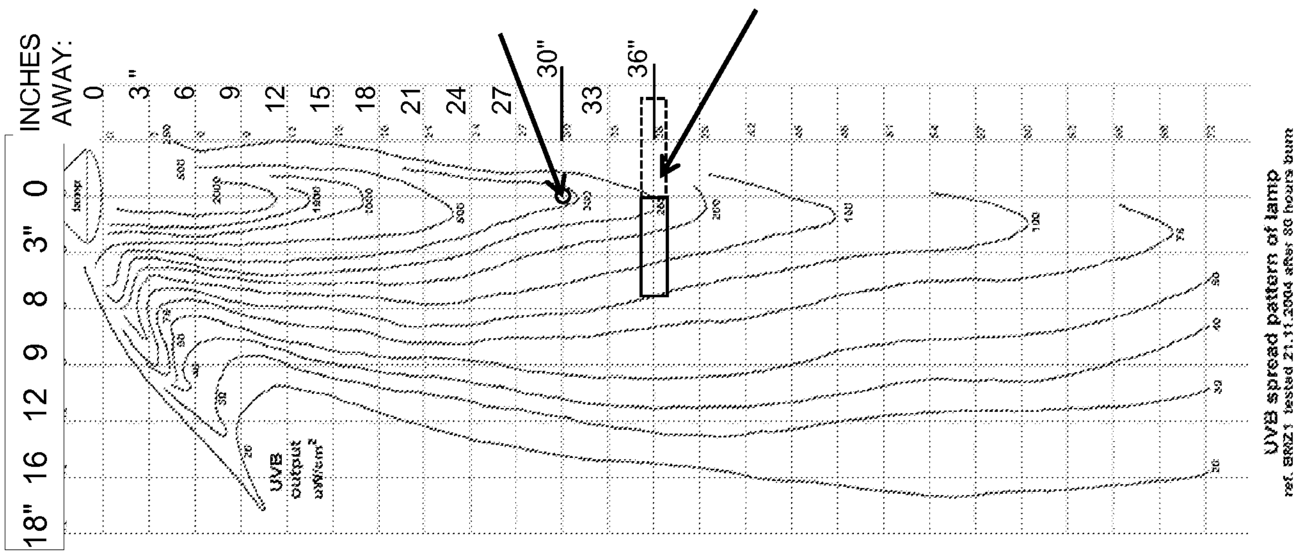


FIG. 8

PRIOR ART

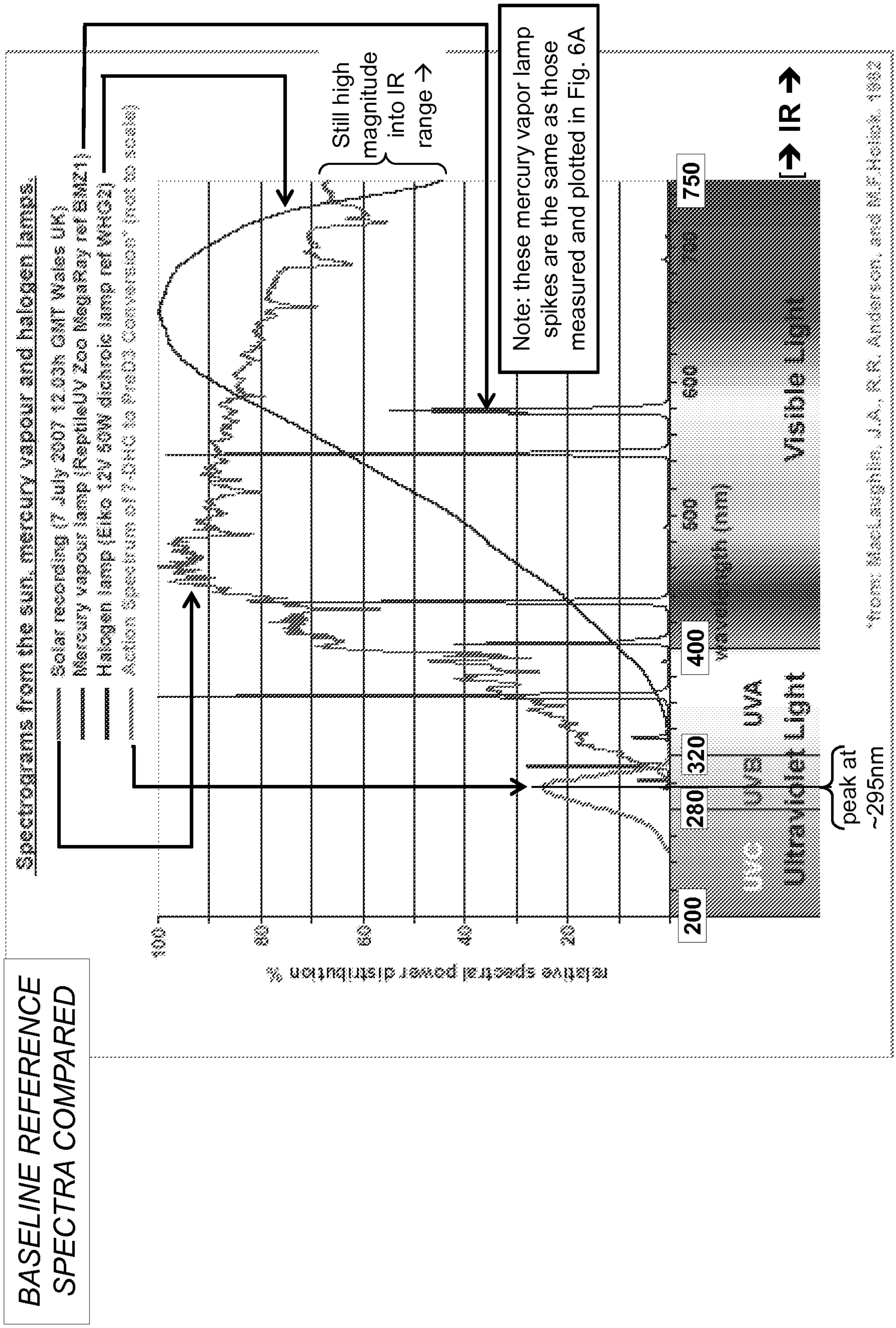

BASELINE REFERENCE SPECTRA COMPARED
Spectrograms from the sun, mercury vapour and halogen lamps.
Solar recording (7 July 2007 12.03h GMT Wales UK)
Mercury vapour lamp (ReptileUV Zoo MegaRay ref BMZ1)
Halogen lamp (Eiko 12V 50W dichroic lamp ref WHG2)
Action Spectrum of 7-DHC to PreD3 Conversion* (not to scale)
Still high magnitude into IR range →
Note: these mercury vapor lamp spikes are the same as those measured and plotted in Fig. 6A
relative spectral power distribution %
100
80
60
40
20
200
280
320
400
500
600
700
750
wavelength (nm)
UVC
UVB
UVA
Ultraviolet Light
Visible Light
[→ IR →
peak at ~295nm
*from: MacLaughlin, J.A., R.R. Anderson, and M.F.Holick. 1982

FIG. 9

FIG. 10

Radiation involved in
Vitamin D3 Production & Regulation

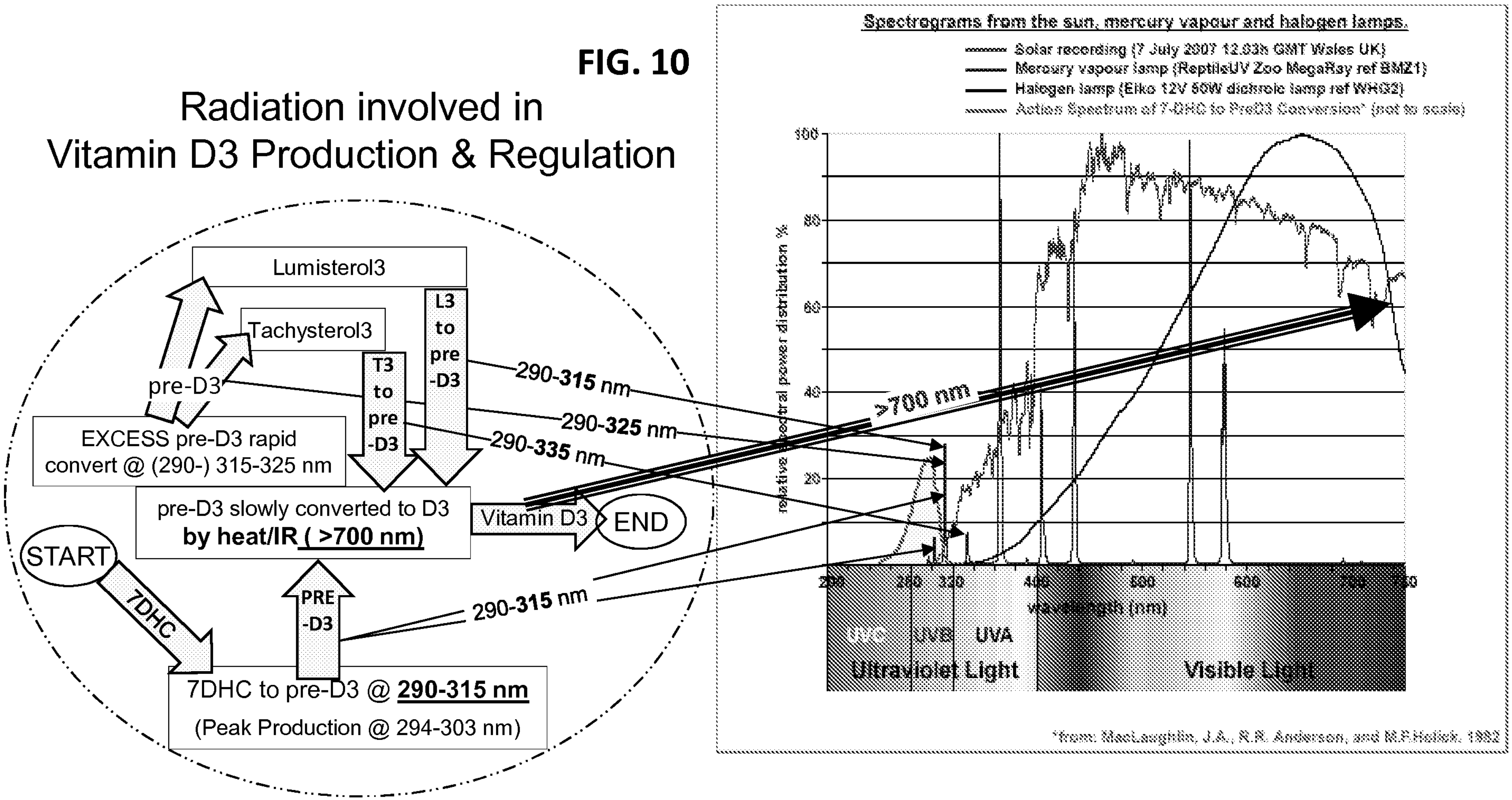


FIG. 11A

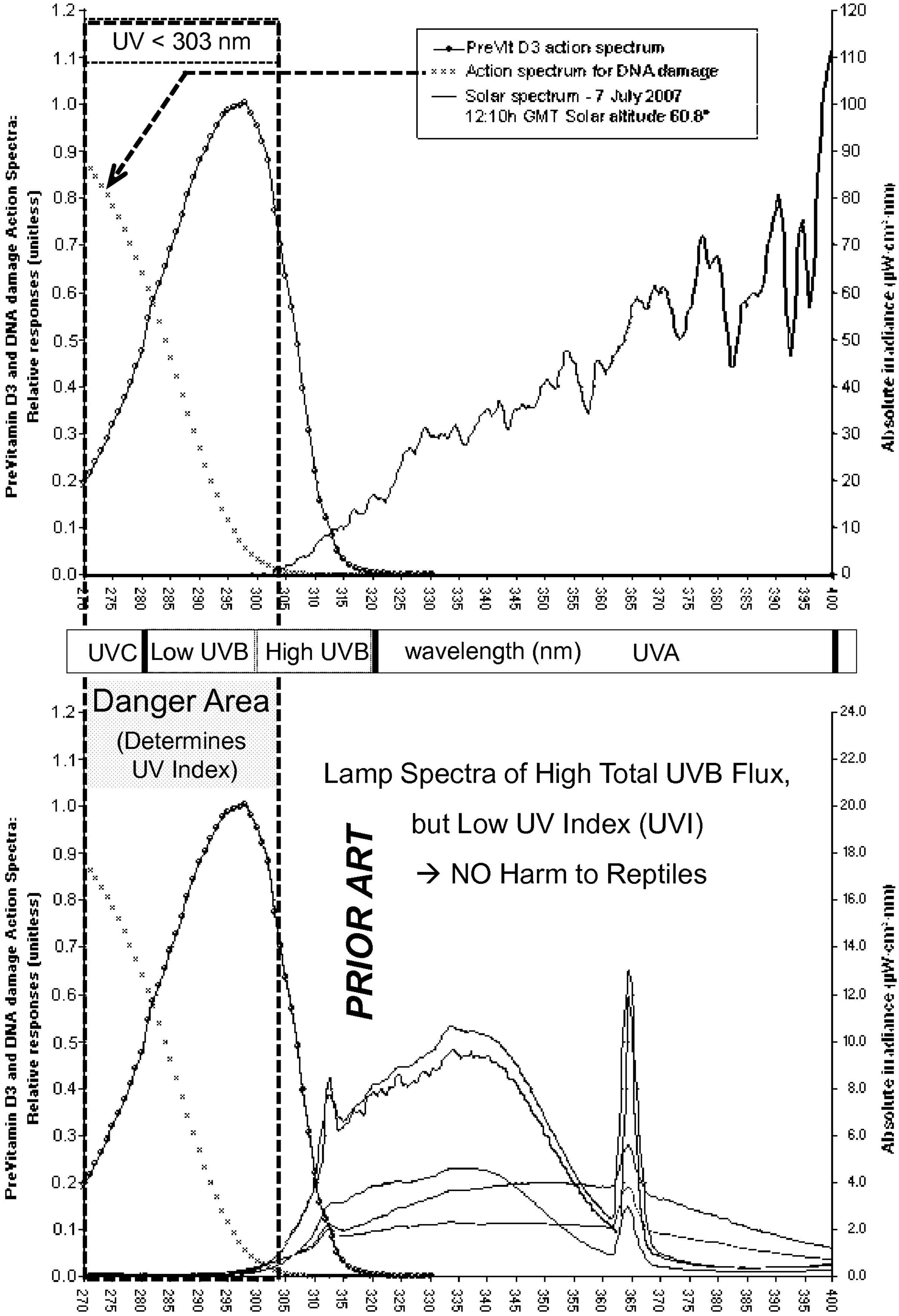

UV < 303 nm
PreVit D3 action spectrum
Action spectrum for DNA damage
Solar spectrum - 7 July 2007
12:10h GMT Solar altitude 60.8°
PreVitamin D3 and DNA damage Action Spectra: Relative responses (unitless)
Absolute irradiance (μW·cm⁻²·nm)
UVC
Low UVB
High UVB
wavelength (nm)
UVA
Danger Area
(Determines UV Index)
Lamp Spectra of High Total UVB Flux, but Low UV Index (UVI)
→ NO Harm to Reptiles
PRIOR ART

FIG. 11B

Lamp Spectra of High UV Index Lamps Known to Cause Harm to Reptiles

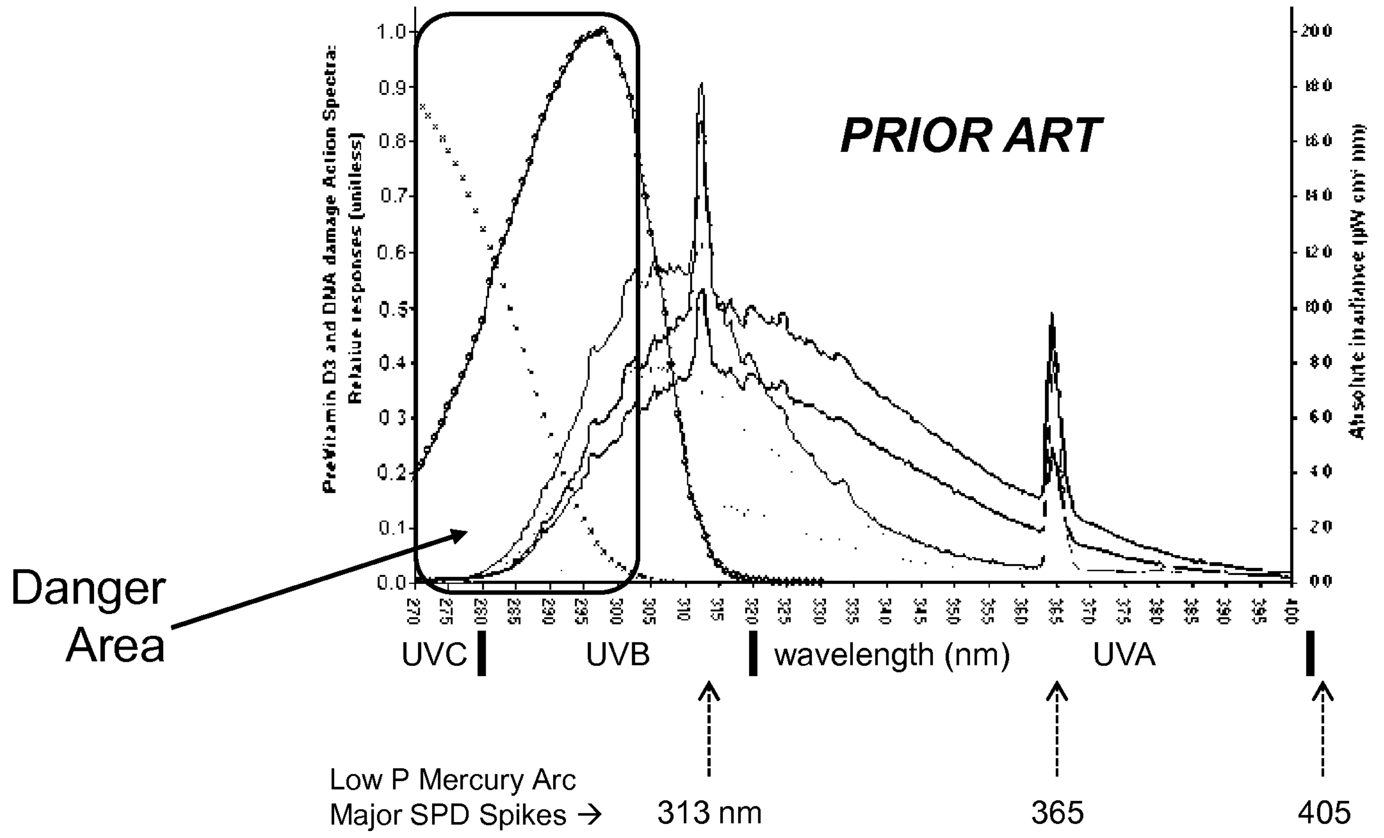


FIG. 12A

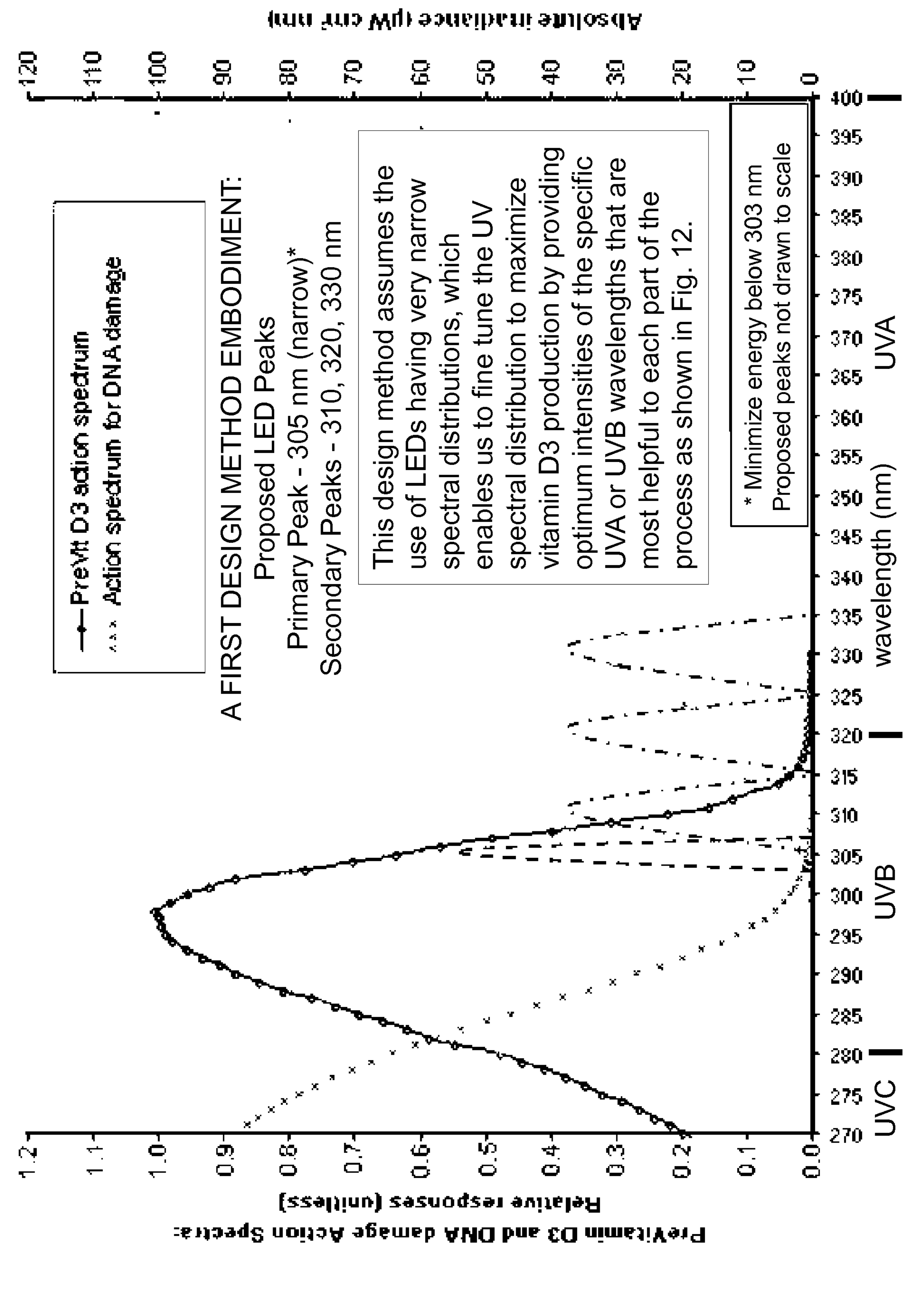
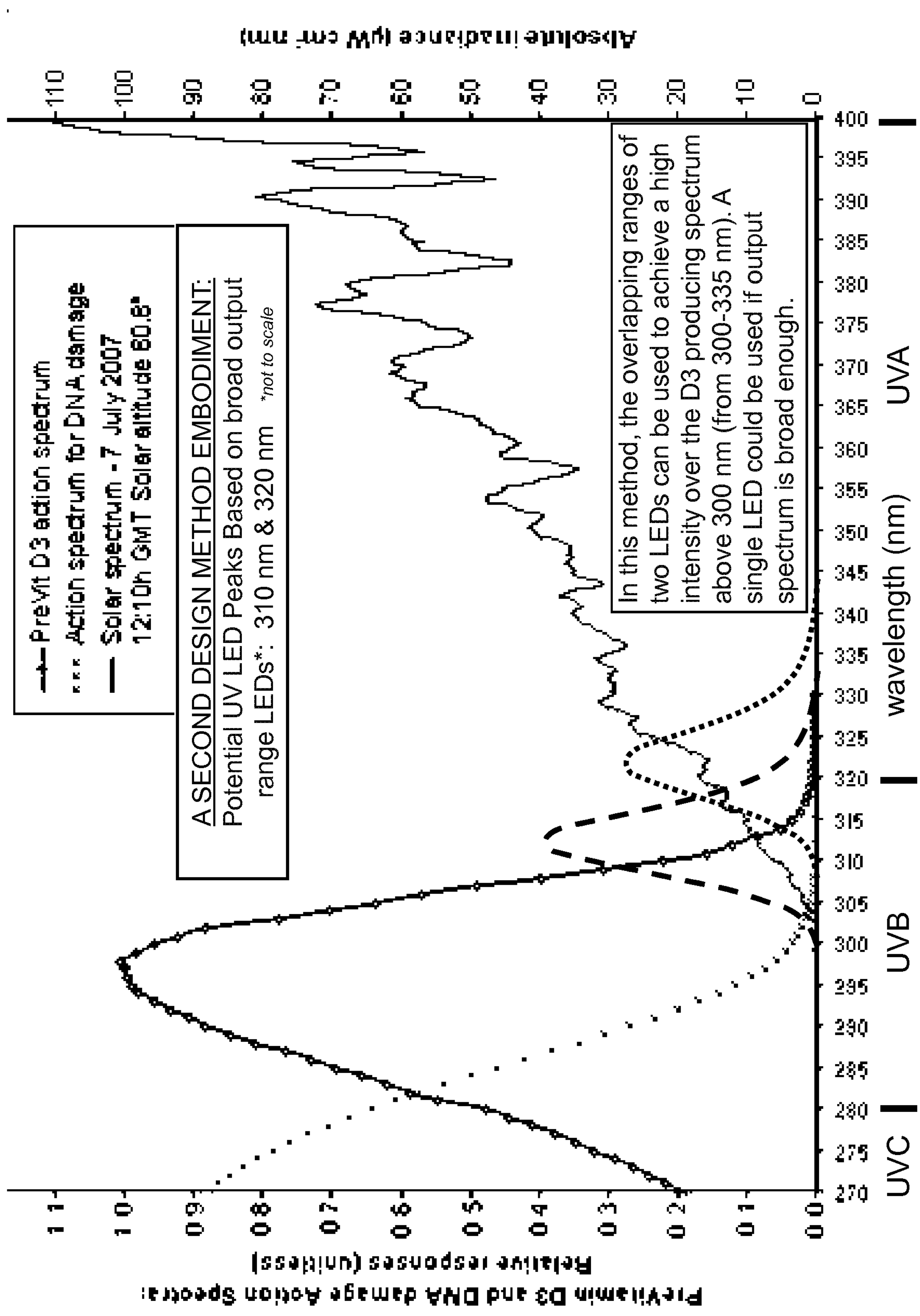

PreVit D3 action spectrum
Action spectrum for DNA damage
A FIRST DESIGN METHOD EMBODIMENT:
Proposed LED Peaks
Primary Peak - 305 nm (narrow)*
Secondary Peaks - 310, 320, 330 nm
This design method assumes the use of LEDs having very narrow spectral distributions, which enables us to fine tune the UV spectral distribution to maximize vitamin D3 production by providing optimum intensities of the specific UVA or UVB wavelengths that are most helpful to each part of the process as shown in Fig. 12.
* Minimize energy below 303 nm
Proposed peaks not drawn to scale
Absolute irradiance (μW cm² nm)
PreVitamin D3 and DNA damage Action Spectra:
Relative responses (unitless)
wavelength (nm)
UVC
UVB
UVA
270
275
280
285
290
295
300
305
310
315
320
325
330
335
340
345
350
355
360
365
370
375
380
385
390
395
400
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
0
10
20
30
40
50
60
70
80
90
100
110
120

FIG. 12B


PreVit D3 action spectrum
Action spectrum for DNA damage
Solar spectrum - 7 July 2007 12:10h GMT Solar altitude 60.6°
A SECOND DESIGN METHOD EMBODIMENT:
Potential UV LED Peaks Based on broad output range LEDs*: 310 nm & 320 nm
*not to scale
In this method, the overlapping ranges of two LEDs can be used to achieve a high intensity over the D3 producing spectrum above 300 nm (from 300-335 nm). A single LED could be used if output spectrum is broad enough.
Absolute irradiance (μW cm⁻² nm)
PreVitamin D3 and DNA damage Action Spectra: Relative responses (unitless)
wavelength (nm)
UVC
UVB
UVA

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US14/67197

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H05B33/00, F21V13/00, A01K1/00 (2015.01)
CPC - H05B 33/00, F21V 13/00, A01K 1/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) Classification(s): H05B 33/00, F21V 13/00, A01K 1/00 (2015.01)
CPC Classification(s): H05B 33/00, F21V 13/00, A01K 1/00; USPC Classification(s): 362/228, 231, 243;

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatSeer (US, EP, WO, JP, DE, GB, CN, FR, KR, ES, AU, IN, CA, INPADOC Data); Proquest; Google; Google Scholar; Search Terms Used: Ultraviolet, UV, IR, visible, reptile, snake, lizard, turtle, animal, infrared, reflector, beam spread, angle, degree, lamp, light, incandescent, LED, heat

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ----- Y	US 2010/0276410 A1 (HUDSON, A. et al.); November 4, 2010; abstract; figures 1B-4; paragraphs [0002]-[0004], [0017]-[0018], [0024]-[0025], [0031]-[0035], [0038], and [0040].	1, 3, 4, 6-8,14-19 ----------- 2, 5, 9-13, 20
Y	US 2006/0271340 A1 (LEVINE, M); November 30, 2006; figure 4A-4C; paragraphs [0009], [0018] [0020]-[0021] and [0028].	2, 10, 20
Y	US 2010/0085761 A1 (DEROME, M.); April 8, 2010; figures 1, and 5; paragraphs [0007], [0038], [0042], [0045].	5
Y	US 2011/0185609 A1 (MIEDEMA, G. et al.); August 4, 2011; figure 5, and 6; paragraphs [0015], [0033] and [0035].	9, 13
Y	US 2009/0207605 A1 (FIELDS, C.); August 20, 2009; figure 3; paragraphs [0009], and [0027]. Y - 10	10
Y	US 7,686,481 B1 (CONDON, P. et al.); March 30, 2010; column 7, lines 6-15, column 7, lines 16-44, and column 9, lines 34-54.	11
Y --- A	Reptiles and UVB. Datasheet [online]. Zoo Med Laboratories, Inc, September 6, 2008; [retrieved on 2015/01/30]. Retrieved from the Internet: <URL: http://web.archive.org/web/20091007071037//http://zoomed.com/Library/ProductDBFiles/Reptiles%20and%20UVB.pdf> (hereinafter 'Zoo Med').	13 --- 12

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 January 2015 (30.01.2015)	10 MAR 2015

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774