Memo
From: Jose-Luis Jimenez, PI of Atmospheric Simulation Chamber Project
To: Oz, RMH, CU Facilicies
Subject: Details of Lights to be used in simulation chamber
Date: 7-May-12, version 1
Update to v3: Pedro Campuzano-Jost, Doug Day, and Jose L. Jimenez, 12-Sep-12

This memo summarizes the design of the UV and visible fluorescent lights that the scientific team has decided on for use in both atmospheric simulation chambers in the 3rd floor of Cristol. As discussed in previous emails, we have ruled out using Xenon Arclamps due to their cost being too high. We have bought and tested the spectra of multiple commercially-available fluorescent lights, and based on those tests we will go with the following design instead:

1. We will use two types of approx. 4 ft fluorescent tubes: UV blacklights ("UV" for short below) and broad- spectrum visible fluorescent tubes ("Vis" for short below).

2. We will retain 22 kW per chamber to power the lights, which is the same that had been specified all along. The power will be distributed as 11 kW for the UV and 11 kW for the Vis.

3. Care should be taken to ensure that the temperature specification (+/-0.5C from 4 to 40C, and reaching 60C without precise control, per our main specs document) can be met with the full power of the lights on (as well as off). This should be subject of a compliance test by the contractor and with participation of the scientists as soon as the chamber enclosures, temperature control system, and lights have been installed.

3a. As per previous discussion with RMH, the temperature of the lights should not exceed 50 C during normal operation, and should ideally hover around between 30 and 40 C, since both types of lights have their maximum output at these temperatures. Temperatures under 25 C should be avoided if possible. Output efficiency curves for the UV and Vis lights can be found at http://cires.colorado.edu/jimenez-group/FTP/Lab/. Note that those are now very similar to each other.

4. As discussed previously, the UV and Vis lights should be controllable independently. Each set of lights should be able to be turned on at levels of 5%, 10%, 20%, 50%, and 100% of total power. E.g. one should be able to turn on 10% of the UV and 100% of the Vis for one experiment, and then switch quickly to 50% of the UV and 10% of the Vis and so on. UV and Vis lights should be intermingled spatially. For the less than 100% settings, the lights that are on should be evenly spaced along the walls of the chamber, so that the lighting of the chamber is as uniform as possible under all settings.

5. The lights should be distributed along the 4 walls of the chamber, and also along the ceiling of the chamber if needed.

6. For the UV we will use T12 (4ft) tubes as those are the only ones available for the BL350 type that we need. There are T8 blacklights available of the BLB type which have a different spectrum and won't work for us. If T8 BL350 tubes became available in the next few months from Sylvania (who has the BL350 patent), we may prefer those to the T12.

7. For UV, we will use 40W tubes for the lights that will be on at 5 or 10% of the power (to ensure more uniformity of the light at lower power levels), and with 115W tubes for the other 90% of the power. This means 28 40W tubes + 86 115W tubes per chamber. The 40W tubes will be Sylvania F40/350BL/ECO (see http://www.amazon.com/Sylvania-24922-350BL-Fluorescent-Black/dp/B002CYW6GI/) with ballasts F40/350BL/ECO (find them e.g. at http://www.mcmaster.com/#ballasts/=hc8ik7). The 115W tubes will be Sylvania FR48T12/350(VHO) (see e.g. http://www.atlantalightbulbs.com/ecart/nw012104/SYLVANIA25251FR48T12.350.htm) with ballasts VHO F48T12/VHO (find them e.g. at http://www.mcmaster.com/#ballasts/=hc8ik7). Our understanding is that all the ballasts that we are considering (for both UV and Vis) run two tubes each. We will consider other ballasts if they have performance or mounting advantages or lower cost, but need to test them and approve the changes.

8a. For the visible lights we will use T5HO tubes (46" long, 54W). These tubes are more efficient and have more intense power consumption and light output per tube than the previously proposed T8s. This in turn will reduce the number of tubes and fixtures needed per chamber (204 T5s instead of 344 T8s, while keeping the maximum power consumption constant at 11 kW for all VIS). There are two bulbs that we are considering: (1) We have so far tested the Sylvania F54HO/865 tube and have found it to be as good as the Verilux bulb proposed before. (2) We are still planning to test a bulb only available in Europe, the Osram F54HO/965. We are importing this bulb right now and will communicate the final choice of bulb as soon as possible to the design team. In any case, since both bulbs are electrically identical, this should not impact the rest of the design process.

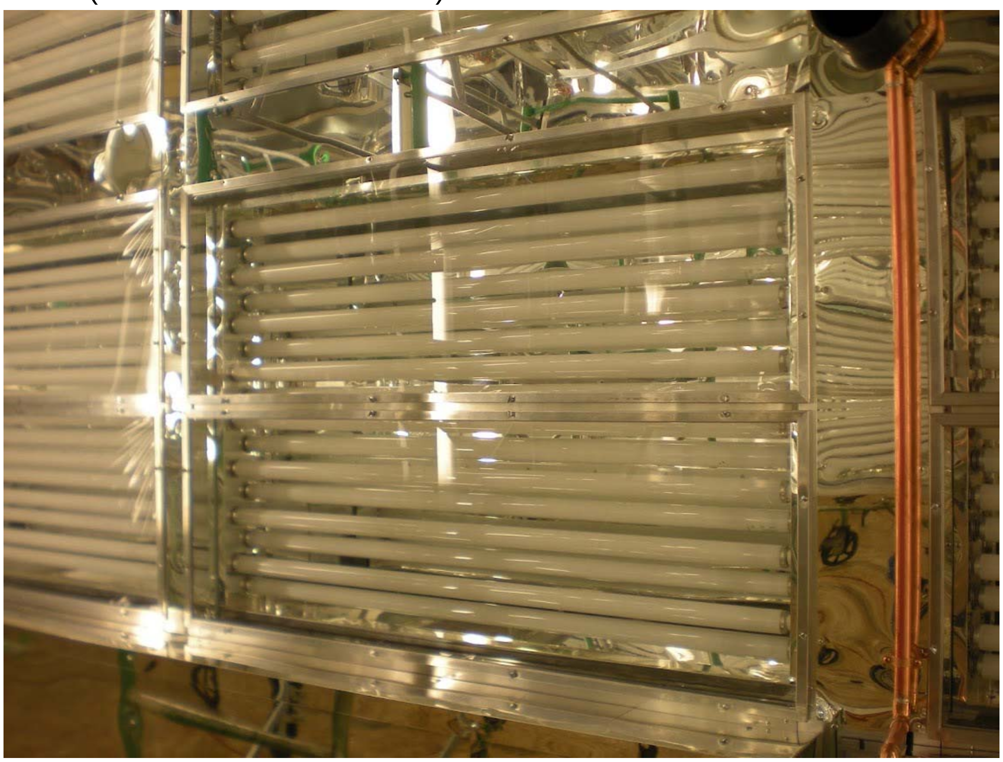
8b. As discussed with RMH, a dimmable ballast to control the output of the VIS lights is very much preferred. However, quality dimmable ballasts such as http://www.1000bulbs.com/product/349/BA-RZT2S5435M.html (which we have tested with the Sylvania bulb and found to be excellent) are very expensive. This is especially the case since there seems to be no dimmable ballasts available to control 4 bulbs (only 2) for T5HO. In order to keep cost down, our options seem to be using either analog input ballasts with a smaller dynamic range (10-100% instead of 1-100%) or some flavor of digitally-controlled dimmable ballast. We are testing the first option currently and will advise soon on a specific model, if possible. If RMH's light contractor prefers a DALI-type dimming system, we would be happy to test those as well if they fit the cost envelope.

9. According to the retail prices for ordering small numbers of bulbs, the cost for all the parts specified above for BOTH chambers is \$35k-\$50k. We would expect the costs to be lower for the contractor since we would be installing a total of 636 tubes of all types. However note that

our cost estimate does not include the fixtures on which the lights are mounted, and there is of course the cost of installation that will need to be added here.

10. For the fixtures and any other materials used, we should avoid plastic parts to the extent possible, to avoid contaminating the clean air around the chamber. The wires should have teflon insulation and the sockets should be metallic with PVC insulation. We can discuss other options if these are too difficult or costly, but need to approve them.

11. One important detail is that the UV and VIS lights are very temperature sensitive, and their light output drops to 20% of the rated output when they are cooled to 4C. For this reason, and also to facilitate the management of the heat output of the lamps in terms of keeping the bag at a stable temperature, all the lights should be mounted behind a sheet of teflon as in the picture below (from the Caltech chamber).



11a. FEP 2 mil. Teflon sheet should be used due to its superior optical properties (over other types of Teflon) in the UV

11b. As stated in 3b, the new VIS lights have the same temperature dependence of light emission as the UV lights. In bench testing, small temperature gradients along the bulb axis led to up to 30% differences in output power for the same bulb. Hence a minimization of thermal gradients, to the extent possible (at least along the horizontal axis of the chamber) is important.

11c. It should also be noted that all dimmable ballasts have a minimum start temperature of 50 F, which could present a problem during cold experiments in the chamber (4C = 39F). If possible, the separate light cooling system should address this (e.g. by allowing reducing the cooling flow or increasing its temperature through the lights during startup).

12. A sheet of Everbrite (Alcoa) will be used behind all lights to maximize reflectivity. Care should be taken to not remove the film covering the Everbrite surface until the fixtures have been installed in the chamber. The film should be removed just before installing the bulbs, and the scientists will clean the Everbrite surface with a solvent to avoid contamination and scratching.

13. In terms of the physical mounting, a staggered mounting system such as the one in the picture is desirable to maximize reflectivity and to facilitate cooling, especially for the very thin T5 lights which tend to run very hot. We will review the design of the light fixtures in the 100% CDs, and are available to discuss this before if needed.