Evaluation of Two Different Tubular Daylighting Devices in UAE Climate

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Abstract
In today’s world nearly all buildings have got lighting fixtures, retrofits and with the advancements in technology and urbanization need for cost effective, highly efficient and eco-friendly sources are becoming more and more important. The motivation behind this project is to evaluate twotubular daylighting devices (TDD) technologies from two different manufacturers, this technology is not very popular up to the moment but there is a good chance for it to become more widely used in the near future. The fixtures were installed at our labs in Ras Al Khaimah in two identical rooms with the size of each room being (6.0X5.4X3.4) m$^3$. Different light parameters were taken into account to be evaluated such as illuminance, CRI and CCT. Also the diagrams of the spectrum and the chromaticity were shown throughout different times of the day.

Keywords: Illuminance, tubular daylighting devices, CRI, visual comfort.

Introduction
We as scientists and engineers need to keep looking for new energy solutions which will contribute in maintaining our environment and meeting human growing needs in the developed applications of life in which used on a daily basis. There are some sources of energy which humans use in their daily life that are known of causing many problems such as oil spills, ecological damage, pollution and human health risks. These are just some of the negative impacts of oil exploration, development and use [1]. The world nowadays have realized that the sun is one of the most valuable and one of the most clean sources of energy and that this energy should be more sustained and utilized in producing economic environment-friendly sources of power, and the same can be said about the energy that is obtained from hydro, wind and hot water reservoirs. The world has recognized clearly the great danger caused by using the conventional sources of energy (especially oil and natural gas) in pollution and destruction of environment, making the renewable energy the best option at all. Therefore, the renewable sources of energy has become in this current era a national income for some countries, so that in the Arab Gulf Countries, which are considered as of the most oil-rich countries in the world [2]. Gulf region is the perfect place to benefit from renewable energy resources since it has all what it takes to benefit from these resources (strong sunshine, abundant space for solar power plants and wind resources) but in the contradiction the six GCC countries are in the top 14 per capita emitters of carbon dioxide in the world. The GCC countries have set a target of saving 3billion barrels of oil equivalent cumulative between 2012 and 2030 [3]. In this paper we try to help reaching this ambitious goal by evaluating an alternative solution that can contribute to reaching this target. This research studies the performance of the tubular daylighting technology when used in the GCC conditions, if this technology is found to have an acceptable performance then it can be used to help reducing the reliance on the conventional energy resources. This research will also help in investigating the feasibility of using the TDDs along the conventional light sources to help reducing energy consumption. This project was conducted in RAK Research and Innovation Center’s labs in Ras Al Khaimah in UAE. The UAE receives over 10 hours of daily sunlight on average – highly significant considering that on average the country has roughly 350 sunny days per year. The total solar energy received is about 6.5 kWh/m$^2$/day and direct normal solar radiation is 4-6 kWh/m$^2$/day, depending on location and time of the year [3-5]. This huge amount of solar radiation makes the tubular daylighting technology worth to be considered and improved in order to account for more green buildings and in return lower electricity bills, more environment friendly technologies and more comfort light technologies. TDDs operate based on the principle of light reflection; as the light ray hits the roof a dome located on the roof collects this ray, this ray is then reflected inside a reflective mirror surface located inside the light tube [6] the ray is then transferred into the room through a diffuser that spreads the light evenly, the TDDs collects a combination of both direct and diffuse light beams into the room, normally vertical window transports either the diffuse or the direct light beam, when the direct light beam is entered into the room it might cause some inconvenience for occupants due to glare, while the diffuse light beam might not reach far corners of the room. The real challenge in designing the TDDs is to design it in a way that provides the most convenient ratio of both the diffuse and the direct beam light [7]. As any other technology the TDD has some advantages and disadvantages. One of the main advantages of this technology is that it can transfer light into the rooms with preferred illuminance values. It can also play a major role in saving energy consumption inside residential and commercial buildings. On the other side it can have up and downs in illuminance values especially in cloudy days. To install a TDD, holes have to be made in the ceiling to fix the tubes. Another drawback is the high initial cost of the TDDs [8].

Experimental set-up
In RAK Research and Innovation Center’s labs there are two types of TDDs from different manufacturers installed in two identical cubical roomsFigure 1 shows the two rooms simulated using Dialux. The room on the left will be referred to as room 1 and the room on the right will be referred to as room 2. This experiment will help in studying the feasibility of
using this technology from more than one manufacturer room 1 is equipped with two 21-inches sized TDDs from one manufacturer while room 2 is equipped with four 13-inches sized TDDs from a different manufacturer. Illuminance measurements using Hera spectrometer from Admesy will be shown in order to study whether these devices work effectively regarding the transferring of light into interiors throughout the day, also the light spectrum figures of each room will be shown throughout the day. The chromaticity diagrams are also shown in the figure. Figure 2 shows the four TDD installed in room 2. The spectrometer was fixed at a height of 1.5 meters above the ground on a movable stand. Figure 3 shows the spectrometer fixed on the stand and connected to a laptop that records the readings. Each room has one window and one door and during the study both of them were covered with dark black sheet to prevent the light from coming inside the rooms from a resource other than the TDDs as shown in Figure 4. The study will show results during clear and cloudy sky.

Figure 1. The two rooms simulated.

Figure 2. TDDs installed in room 2 at the roof.

Figure 3. The stand holding the spectrometer.
values for room 1 in 2nd December between 10:30 AM until 3:30 PM, and the average CCT value during that period was 4702 K. For room 2 the CCT values were obtained in 1st December from 10:30 AM until 3:30 PM, with an average CCT value of 4068 K. The CRI values were also obtained for both of the rooms during the same periods of calculation of CCT values, the CRI values of both rooms was quiet high for room 1 the average CRI value was 97 while for room 2 the average CRI value was 94. 12. The spectrum for both of the rooms is illustrated in figures 9 for room 1 and figure 10 for room 2. The snapshots were taken on 2nd December for room 1 and on 1st December for room 2 between 10:30 and 3:30. The snapshot on the upper left represents the spectrum on 10:30 while the adjacent one represents the spectrum at 11:30 and so on until we reach the snapshot on the bottom right which represents the spectrum at 3:30.

Results and Discussion
The light intensity for both rooms were carried out during the period from 8:15 AM until 5:15 PM in 4th December 2015 for room 1 and in 6th December 2015 for room 2. Figure5 presents their performances during these two days. The sky was clear with no significant clouds effects. Also the sunset was around 5:30 PM. The intensity results for both rooms were different; room 1 had higher illuminance values with peak value of 633.6 lux which occurred at 12:30 PM while room 2 had a peak value of 260.20 lux which occurred at 12:04 PM, as it is clear from the figure the illuminance values for room 1 are more stable while the curve of room 2 has many fluctuations. The average illuminance value for room 1 during that period was 412.24 lux while for room 2 it was about 111.76 lux during the same period. Other values were obtained for room 2 of Figure 6 in 7th December 2015 from 12:15 PM until 5:15 PM during that day the sky was cloudy so this figure shows the illuminance values when using TDD technology in a cloudy day. The maximum illuminance value during that period was about 126.7618 lux, which occurred at 12:28 PM which is relatively low and inconvenient. The values recorded after 4:00 PM were very low that they didn’t exceed 50 lux at their peak. The average illuminance during that period was 60.25 lux.

The values of the correlated color temperature (CCT) were also obtained for both of the rooms, figure 7 illustrates CCT

Figure 4. The window covered with black sheet

![Figure 4](image)

Figure 5. Light intensity values for rooms 1 and 2 from 8:15 AM till 5:15 PM.

![Figure 5](image)

Figure 6. Light intensity values for room 2 in a cloudy day from 12:15 PM till 5:15 PM.

![Figure 6](image)

Figure 7. CCT values of room 1 from 10:30 AM till 3:30 PM.

![Figure 7](image)

Figure 8. CCT values of room 2 from 10:30 AM till 3:30 PM.

![Figure 8](image)
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References
[8] Tukur, R. B. Harnessing daylight potentials as a tool for visual and thermal comfort in residential buildings.

Conclusion
The illuminance values for both of the rooms were obtained, the results shows that the TDD technology can be quiet useful for UAE conditions. Althoughthese values were measured in December which is in fall and the sun is not at its highest radiation levels still the lux levels were acceptable. During the spring and summer the results are expected to be even better. There were differences in the results of the light intensity between the two rooms. In room 1 the values were higher than the values of room 2 with an average illuminance of 412, 24 lux for room 1 and 111. 76 lux for room 2, which tells that the quality of the light issued from a TDD technology depends on the manufacturer and could be different from one manufacturer to another. One of the disadvantages of this technology is the varying light levels during a cloudy day which might cause inconvenience for occupants. One advantage of the TDD technology was the CRI values which were high throughout the days that the tests were performed.

Figure 9. Spectrum variation of room 1 from 10:30 until 3:30.

Figure 10. Spectrum variation of room 2 from 10:30 until 3:30.