UVGI: An Effective Tool for Better IAQ and Energy Efficiency in HVAC

Ultra Violet lamp installed in an air handling unit

By Dr. Avinash D. Kulkarni
Chairman, Aeropure UV Systems Pvt. Ltd., Pune

The germicidal capability of UVC light has been known for over a century and the use of UVC lamps to irradiate cooling coils in an AHU has been known for over three decades[1], but wider acceptance of the concept is relatively recent. Since March 2003, UVC irradiation of cooling coils has been incorporated in the *Facilities Standards for Public Buildings Services* by U.S. General Services Administration Office of the Chief Architect[2]. This new standard is meant to address the problem of Indoor Air Quality (IAQ), particularly to overcome "Sick Building Syndrome".

HVAC Operation: Current Practice

Normal operation of an AHU, in the absence of UVC, leads to formation of coating of mold, mildew and other deposits on cooling coils. This deposit, in small thickness of even a few hundred nanometers, has far reaching adverse effects on the performance of the AHU in many ways.

1. It reduces the heat transfer between the coil and the air passing over it which leads to reduced capacity of the HVAC system and also lowers the energy efficiency of the overall cooling system.
2. As the gap between the fins in cooling coils is small, any build up of deposits increases the pressure drop, leads to reduced airflow and further contributes to the energy inefficiency.
3. Sticky nature of these deposits attracts dust which increases the rate of build up of deposits.
4. In the absence of regular, frequent clean up of coils, these deposits are blown away and accumulate in ducts, causing further contamination of air and unhygienic conditions.
5. These deposits serve as breeding grounds for microbes, leading to further deterioration of IAQ.

In an effort to overcome the above issues in HVAC systems, periodic cleaning of cooling coils is followed. This practice, though better than not cleaning the coils at all, has its own drawbacks, such as:

About the Author

Avinash D. Kulkarni, chairman of Pune-based Aeropure UV Systems and various other companies is also the president of Indian Society of Lighting Engineers. With an engineering degree from IIT Bombay, a doctorate from University of Pennsylvania and masters in business administration, he worked for 8 years as senior research engineer with Westinghouse - Lamps Division and received a citation as an inventor and obtained 5 US Patents. After returning to India in 1979, he started his own company and was the recipient of a national award as an Outstanding SSI Entrepreneur 1985. He received the Distinguished Alumnus award from IIT Bombay in 1983.

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1. High maintenance cost of labour and materials.
2. Wastage of water and chemicals; also resulting in pollution.
3. During the cleaning operation there is no ventilation; causing further deterioration of IAQ.
4. Frequent cleaning shortens the life of cooling coil.

The frequency of cleaning of coils ranges from once a week (very rare) to once in six months.

Table 1: Average KWH Consumption per day

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2008	-	-	-	2593	3041	2795	2200	1885	1845	1602	1602	1507
2009	1163	1368	1840	2108	2231	2287	1893	1667	1863	1810	1573	1354
2010	1235	1495	1769	1991	2069	1958	1774	1493	1635	1716	1520	-
Infrequent Cleaning				Weekly Cleaning					UVGI Installed			

HVAC Operation with UVGI

A vastly superior alternative to the periodic cleaning is to use Ultra Violet Germicidal Irradiation (UVGI) of cooling coils by UVC lamps. Correctly designed, the UVGI system eliminates the root cause of the problem by preventing formation of mold, mildew or any deposit on the cooling coil. By doing so, it overcomes all the five original problems of AHU, without any of the four drawbacks associated with periodic coil cleaning. UVGI thus maintains the cooling coils in brand new condition, thereby maintaining peak performance of the HVAC system. Thus the

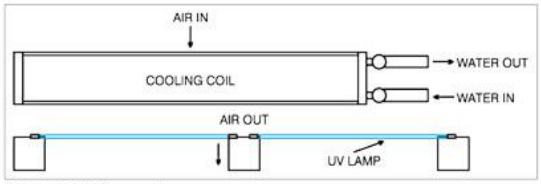

Figure 1: UVGI mounting

UVGI system addresses all the nine concerns of the current AHU operating practice of periodic cleaning of coils. All these benefits stem from 'Surface Disinfection' of cooling coils by UVGI.

The benefits do not stop there. There is yet another very significant benefit in terms of enhancement of IAQ which stems from 'Air Disinfection' by UVGI. Because of strong germicidal properties of UVC, a very large fraction of microbes present in the air are killed and eliminated. The indoor air with lower microbe content feels fresh and is healthy, devoid of staleness. That also takes care of "Sick Building Syndrome". The design of the system and the mounting option selected play a crucial part in the UVGI system effectiveness. *Figure 1* for instance shows a design without reflectors for greater emphasis on air quality.

To demonstrate the effectiveness of this UVGI system, three case studies are presented here.

Case Study 1: Energy Conservation in an Office Building

Persistent Systems Ltd is a leading Pune based IT Company and the selected office building is ten years old with six floors, being served by 17 AHUs. Energy meters are installed in the building to monitor KWH usage of HVAC in the entire building, and monthly energy consumption data has been available from April 2008 onwards. For each month the KWH consumption data for HVAC is divided by the number of working days in the month and average daily KWH consumption data is computed.

In March 2010 a total of 78 UVGI units were installed in all 17 AHUs (*Table 1*). It should be noted that weekly cleaning of cooling coils in all AHUs was being practiced since September 2008, and prior to that coil cleaning was unscheduled, irregular and considered as 'no cleaning' basis.

Average daily KWH consumption for every month, from April 2008 through November 2010 as reported by Persistent Systems staff is summarized in *Table 1*. Out of the total 32 data points, 5 are for "Infrequent cleaning' basis (from April 2008 to August 2008), 19 are for weekly cleaning (September 2008 to March 2010) and the remaining 8 month data is with UVGI units installed (and no mechanical cleaning). Proper analysis of the data should enable us to check reliability of the collected data and establish beneficial effects if any, of UVGI over infrequent cleaning and weekly cleaning of the coils.

a) Testing Reliability of the Data

In *Table 1*, average KWH consumption figures for two seven month periods, from September 2008 to March 2009 and again September 2009 to March 2010 can be compared. During these periods of both the years, weekly cleaning of coils was being followed. The average daily KWH consumed during the two periods are 1561 and 1585 KWH respectively, which are only 1.5% different. This marginal difference in energy consumption data under the same operating condition of weekly cleaning suggests that the data collection is consistent and reliable.

b) UVGI units v/s Infrequent Coil Cleaning

In *Table 1*, average energy consumption data for a five month period from April 2008 to August 2008 and from April 2010 to August 2010 can be compared. During 2008, in these months, there was infrequent cleaning of coils. In 2010, UVGI units were installed and no mechanical cleaning of coils was done. The average daily KWH consumption with 'no cleaning' was 2503 KWH and with UVGI units it was 1857 KWH, a staggering 25.8% reduction.

c) UVGI units v/s Weekly Coil Cleaning

In *Table 1*, the average energy consumption data for an eight month period from April 2009 to November 2009 and April 2010 to November 2010 can be compared. The average daily KWH consumption for these two years is 1929 KWH (with weekly cleaning) and 1769 KWH (with UVGI units installed), indicating a drop in energy consumption by 8.3%. It should be noted that after installation of UVGI units, manual coil cleaning was

Table 2: CFU counts in air

Location of Air Sample Measurement	Pre-UVGI Installation Bacteria Count	Post-UVGI Installation (10 days) Bacteria Count	% Reduction in Bacteria Count
Return Air Duct (aggregate effect)	38	12	70%
Work Area Full Occupancy	35	6	83%
Work Area 30% occupancy	15	9	40%

discontinued and even then 8.3% energy was saved.

In a detailed testimonial issued by M/s Persistent Systems Ltd., all the critical energy saving data of 25.8% and 8.3%, as indicated above have been corroborated. In a subsequent communication, Persistent indicated zero failure rate of UVGI units and its components (UV lamp and ballast) during one year of operation.

Conclusion

The energy consumption data collected at Persistent is quite reliable. The use of UVGI units resulted in 25.8% and 8.3% reduction in energy consumption over infrequent cleaning and weekly cleaning of cooling coils respectively. The 8.3% reduction in the energy consumption over weekly cleaning is perhaps more significant. One should certainly expect a 10 to 15% reduction in energy consumption over monthly coil cleaning, which is a more common practice in HVAC maintenance. Also, the energy saving is realized round the year, not just during a few summer months, although saving in summer months is maximum.

Case Study 2: Indoor Air Quality in an Office Building

In an office of a major IT company in Pune a trial installation of UVGI units was made in an AHU of 48,000 CFM. The primary concern here was to minimize the spread of airborne infections within the air conditioned work space. Although there are several factors involved in quantifying IAQ, perhaps the most important is the microbe count in the air.

Figure 2: Colonies formed by microbes

In order to measure the microbe count in air, an agar-agar filled petri dish is exposed to the indoor air for 30 minutes, followed by incubation at 37°C for 24 hours. The number of colonies formed by microbes, which is called **Colony Forming Units** (CFU) is counted, and is a measure of the microbe count in the air (see *Figure 2*).

Microbe count at three selected locations was done prior to and ten days after UVGI units installation. These locations were i) Return Air Duct, ii) Work Area with Full Occupancy and iii) Work Area with 30% Occupancy. The resulting CFU counts before and after UVGI units are summarized in *Table 2*. The data indicates a drastic drop of ~75% in microbe count in the areas with high microbe count and a relatively modest drop of 40% in the area which was already low in microbe count. Occupants reported freshness in the air, free of staleness.

Conclusion

There is a drastic reduction in microbe count in the air after UVGI units installation. This factor alone enhances IAQ and eliminates the possibility of "Sick Building Syndrome".

Case Study 3: Third Party Validation

After a presentation in an ISHRAE forum, an MNC well known for providing building automation solutions with its office in Pune, expressed interest in a formal evaluation of these UVGI units. Subsequently it was decided to install UVGI units in two AHUs of 12000 CFM each, serving a common work area, a large hall in their Pune campus. Prior to this installation, coil cleaning was done once in two months; after installation the cleaning was discontinued.

Although full and final report should be available by end of June 2011 (six months after initial installation) interim results available so far are as follows:

1. Air flow rate through the AHUs, which is closely monitored periodically, has gone up by 5% after two months of usage (see *Figure 3*).

2. Microbe count was measured in five different locations in the hall using two types of media in petri dishes: nutrient-agar, which responds to all types of microbes, and blood agar, which is more responsive to pathogens. Following the CFU measurement procedure described earlier, along with the Gram Stain technique[3], CFU pertaining to different microbes such as Gram Positive Cocci (GPC), Gram Negative Bacilli (GNB), Gram Positive Bacilli (GPB) and fungi were determined. For each location in the hall, total CFU was computed by taking the above four constituents for each medium, and the average value of CFU using both media was calculated and plotted in *Figure 3*. The CFU data in *Figure 4* are for the initial state, prior to turning the UVGI units on and the second one after 90 days of operation, with no mechanical cleaning in between.

Conclusion

Even 5% enhancement in CFM in AHUs is considered a significant improvement. The drop in CFU for both the media is very similar and it is uniform for all microbes, including

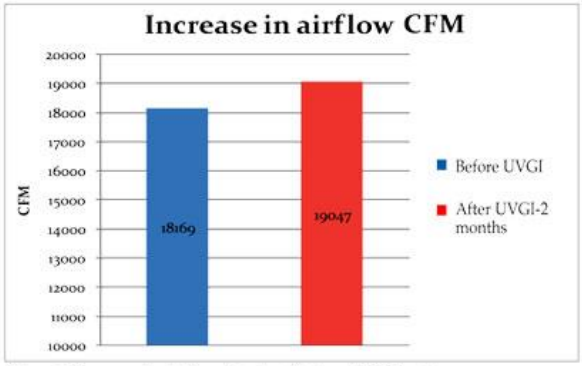

Figure 3: Increase in air flow after installation of UVGI units

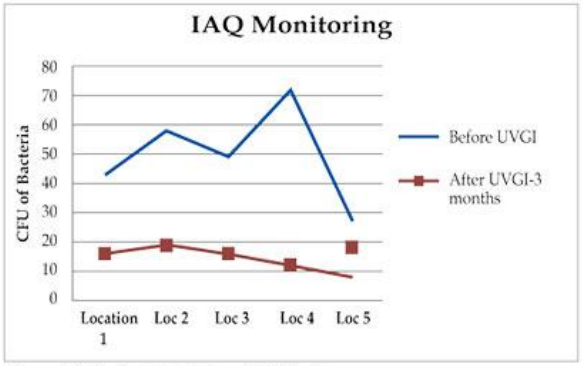

Figure 4: IAQ after installation of UVGI units

pathogens. A 73% reduction in count for all microbes means a very marked enhancement in IAQ.

"Quality is Free" is the title of a book authored by the legendary American quality guru Philip B. Crosby. After initial payback period of less than 18 months, both IAQ enhancement and energy savings are really free; saving in the maintenance cost of AHUs pays for maintenance of UVGI units.

Acknowledgement

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