Mechanical Redesign:

Calvert Memorial Hospital is 185,000 square feet. The portion of the building studied in this report is the 2^{nd} – 5^{th} floor patient tower which is approximately 38,265 square feet. The mechanical redesign involves many different ideas: The removal of the 2^{nd} – 5^{th} patient tower heat pumps, the new variable-air-volume system design loads, the selection of an appropriate air handling unit and enthalpy wheel, the layout of the overhead ducted system, and the installation of UVGI (ultraviolet germicidal irradiation) fixtures in the patient rooms.

1 – Removal of Heat Pumps:

The existing 2^{nd} – 5^{th} floor patient tower rooms of Calvert Memorial Hospital were originally served by water-source heat pumps. These heat pumps are in poor condition and have created numerous problems with the indoor air quality; therefore, they will be removed. Not only will the removal of these systems increase the air quality, but there will also be a significant reduction in the number of equipment to be maintained. Also, hospitals often undergo many modifications. Installing a newly ducted system will provide a more flexible system for these future renovations.

2 –Existing Mechanical Equipment & New Building Loads:

New loads were performed for the 2^{nd} – 5^{th} floor patient tower rooms by using the Hourly Analysis Program (HAP). These design loads were entered in an excel spreadsheet. See Appendix 1 – Room Load Data. A brief summary of the output data from the analysis for the 2^{nd} – 5^{th} floor patient tower are shown in the following table.

Floor	Supply Air (cfm)	Return Air (cfm)	Exhaust Air (cfm)
2	9,380	8,695	790
3	10,060	9,375	790
4	10,060	9,375	790
5	10,060	9,375	790
Totals:	**39,560**	**36,820**	**3,160**

Table 1 – New Patient Tower Loads (Per Floor)

In the next sections, the building's chilled water plant and boiler plant were examined to see if any modifications need to be made due to the added building loads.

Chilled Water Plant

The existing chilled water plant is capable of providing 630 tons of cooling to the hospital. The current total cooling load for the hospital is 450 tons (5115.5 MBH). However, this load refers to 121,500 square feet of the existing hospital. The total area of the newly designed 2^{nd} – 5^{th} patient tower rooms with the removed heat pumps is 38,265 square feet. In performing load calculations for the 2^{nd} – 5^{th} floor patient tower by the Hourly Analysis Program, a new cooling load of 132.5 tons was reported. The existing 450 ton load and the new 132.5 ton load were added together to determine the hospital's new total cooling capacity of 557.5 tons. This cooling load compares favorable to the rated capacity of the existing chilled water plant (630tons). No modifications need to be made.

Boiler Plant

After a study of the building envelope heating load and the reheat load for the existing hospital campus, a total connected heating load for Calvert Memorial Hospital was found to be 4,350 MBH. In determining the new total heating load, the Hap analysis was again taken into consideration. The newly renovated patient tower heating load was found to be 297.7 MBH. The existing hospital heating load of 4,350 MBH was added to the newly calculated patient tower load of 297.7

MBH to establish the hospital's new heating load of 4,647.7 MBH. This heating load compares favorable to the rated capacity of each boiler, which is 5,021 MBH. No modifications need to be made.

3– Air Handling Unit Selection:

The total supply air to the building was used to determine the new air handling unit. Carrier AHUBuilder v5.42 was used to make the selection. The outdoor 39RW size 95 unit, shown in the picture to the right, was chosen with a designed capacity of 47,625 cfm.

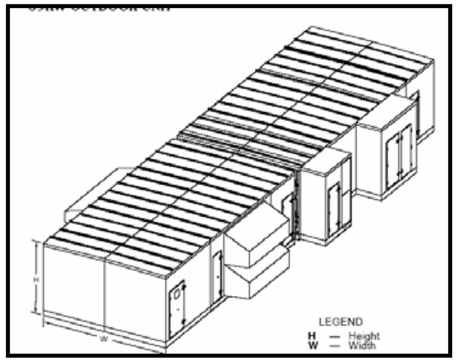

Figure 8 – 39 RW Outdoor Unit

The size 85 39RW unit with a rated capacity of 42,667 cfm could have also been selected for this design. This unit would allow an extra 3,107 cfm of available air in the case of future expansion. Due to the constant changes made to medical facilities, the next size unit (size 95) was the preferred choice. With this unit there was an excess of 8,065 cfm for future renovations or expansions to the hospital.

The different costs associated in estimating the total cost for the air handling unit were broken down into the categories seen below. When added together, the final cost of the air handling unit was determined to be $298,475.

AHU (47,625 CFM)	Cost ($)
AHU + Installation	$53,475
Electrical	$25,000
Ductwork	$60,000
Insulation	$35,000
Piping	$72,500
Var. Freq. Controllers	$37,500
Rigging	$15,000
AHU total	$298,475

Table 2 – Cost of 39 RW Outdoor Unit

The newly selected air handling unit will be placed on the roof of the fifth floor patient tower and serve the entire 2nd – 5th floor patient tower. The following schematic represents a visual interpretation of the air distribution to each floor.

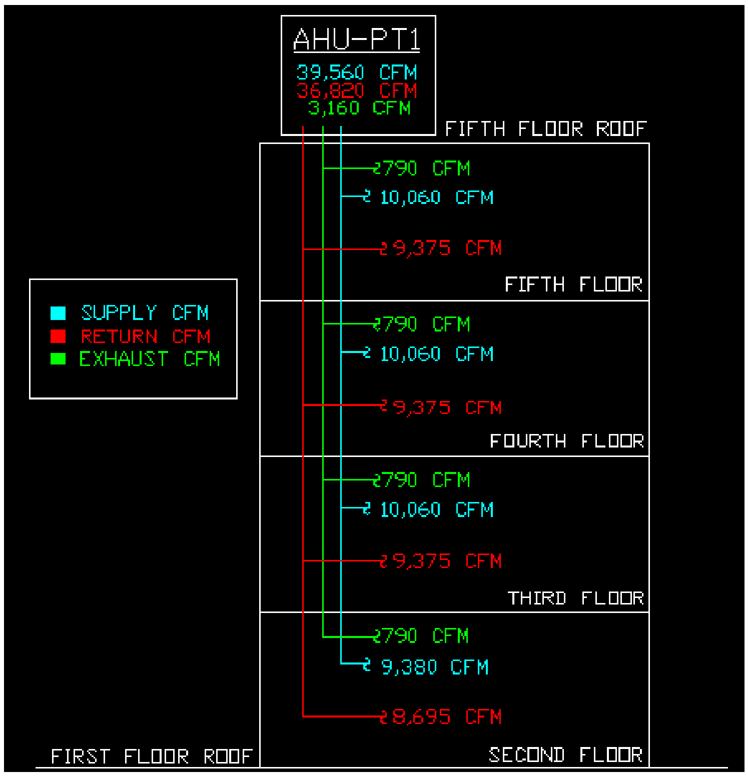

Figure 9 – AHU Distribution To Each Floor

4 – Enthalpy Wheel:

The enthalpy wheel cools and dehumidifies the outdoor air in the summer, lowering the load on the cooling coil. In the winter, the enthalpy wheel can be used to heat and humidify the outdoor air, eliminating the need for the humidifier. In this section, an explanation of the selection of the enthalpy wheel will be explained. The energy savings from the wheel will be explored using Bin Maker Plus hourly weather data for Baltimore, MD. The enthalpy wheel was selected from the NovelAire Technologies Energy Conservation Wheel Brochure.

Enthalpy Wheel Selection

Due to the newly calculated $2^{nd} – 5^{th}$ floor patient tower loads, 3,160 cfm of ventilation air is needed. By using NovelAire's Energy Conservation Wheel Brochure, the ECW 604 model was chosen. See Appendix 2 – Enthalpy Wheel Engineering Details for the model selection. This model Is rated for an airflow of 6,000 cfm. Even though the building's current ventilation requirements are roughly half of that, the larger wheel was chosen in the case of future expansion and renovations of the hospital. Also, the efficiency of the wheel was better for this particular selection. NovelAire's Wheel Selection Program determined the wheel efficiencies to be 84.3% for the sensible load, and 82.1% for the latent load. See Appendix 3 – Enthalpy Wheel Selection Program for an example of the program outputs.

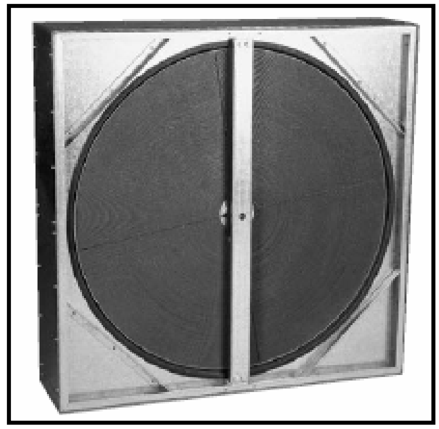

Figure 10 – Enthalpy

A sales representative from NovelAire Technologies was contacted to get a cost of the ECW-604 enthalpy wheel. The wheel is roughly $3,000.

Enthalpy Wheel Energy Savings

In using the Bin Maker Plus program, hourly weather data was extracted for Baltimore, MD because accurate bin data was not available for Prince Frederick, MD. These bins contain information on the humidity ratios and dry bulb temperatures that occur in Baltimore, MD over a certain number of hours. As stated before, these bins were based on humidity ratio and were used to determine the energy and cost savings of the wheel at different times throughout the course of one year.

midpts Gr/Lb	DB	Total Hrs	OA cfm	Face Velocity	Sensible Eff	Latent Eff	Leaving DB	Leaving Gr/lb
157.5	87.6	2	3160	160.94	84.3	82.1	74.4	76.2
152.5	91.9	1	3160	160.94	84.3	82.1	75.1	75.3
147.5	84.5	11	3160	160.94	84.3	82.1	74.0	74.4
142.5	83.6	23	3160	160.94	84.3	82.1	73.8	73.5
137.5	82.2	37	3160	160.94	84.3	82.1	73.6	72.6
132.5	81.5	48	3160	160.94	84.3	82.1	73.5	71.7
127.5	80.1	62	3160	160.94	84.3	82.1	73.3	70.9
122.5	79.3	122	3160	160.94	84.3	82.1	73.1	70.0
117.5	80.5	151	3160	160.94	84.3	82.1	73.3	69.1
112.5	79.5	140	3160	160.94	84.3	82.1	73.2	68.2
107.5	79.6	107	3160	160.94	84.3	82.1	73.2	67.3
102.5	79.2	120	3160	160.94	84.3	82.1	73.1	66.4
97.5	80.7	88	3160	160.94	84.3	82.1	73.4	65.5
92.5	80	79	3160	160.94	84.3	82.1	73.3	64.6
87.5	78.7	84	3160	160.94	84.3	82.1	73.1	63.7
82.5	79.1	116	3160	160.94	84.3	82.1	73.1	62.8
77.5	79.7	88	3160	160.94	84.3	82.1	73.2	61.9
72.5	81.6	82	3160	160.94	84.3	82.1	73.5	61.0
67.5	80.9	89	3160	160.94	84.3	82.1	73.4	60.1
62.5	78.8	66	3160	160.94	84.3	82.1	73.1	59.2
57.5	79	61	3160	160.94	84.3	82.1	73.1	58.3
52.5	77.4	58	3160	160.94	84.3	82.1	72.8	57.4
47.5	76.1	50	3160	160.94	84.3	82.1	72.6	56.5
42.5	77.9	24	3160	160.94	84.3	82.1	72.9	55.6
37.5	75.4	17	3160	160.94	84.3	82.1	72.5	54.7
32.5	74.6	5	3160	160.94	84.3	82.1	72.4	53.8
27.5	74.6	5	3160	160.94	84.3	82.1	72.4	53.0

Table 3 – Baltimore, MD Bin Data

To begin the calculation, the sensible and latent loads of the building were computed for each humidity ratio midpoint without the enthalpy wheel. After totaling the sensible and latent loads for each bin, they were combined to get the building's total load of 255,253,955 BTU for one year. When performing the same calculation with the added enthalpy wheel, the new building load was determined to be 107,471,020 BTU for the year. The chart below shows a breakdown of enthalpy wheel savings per time period.

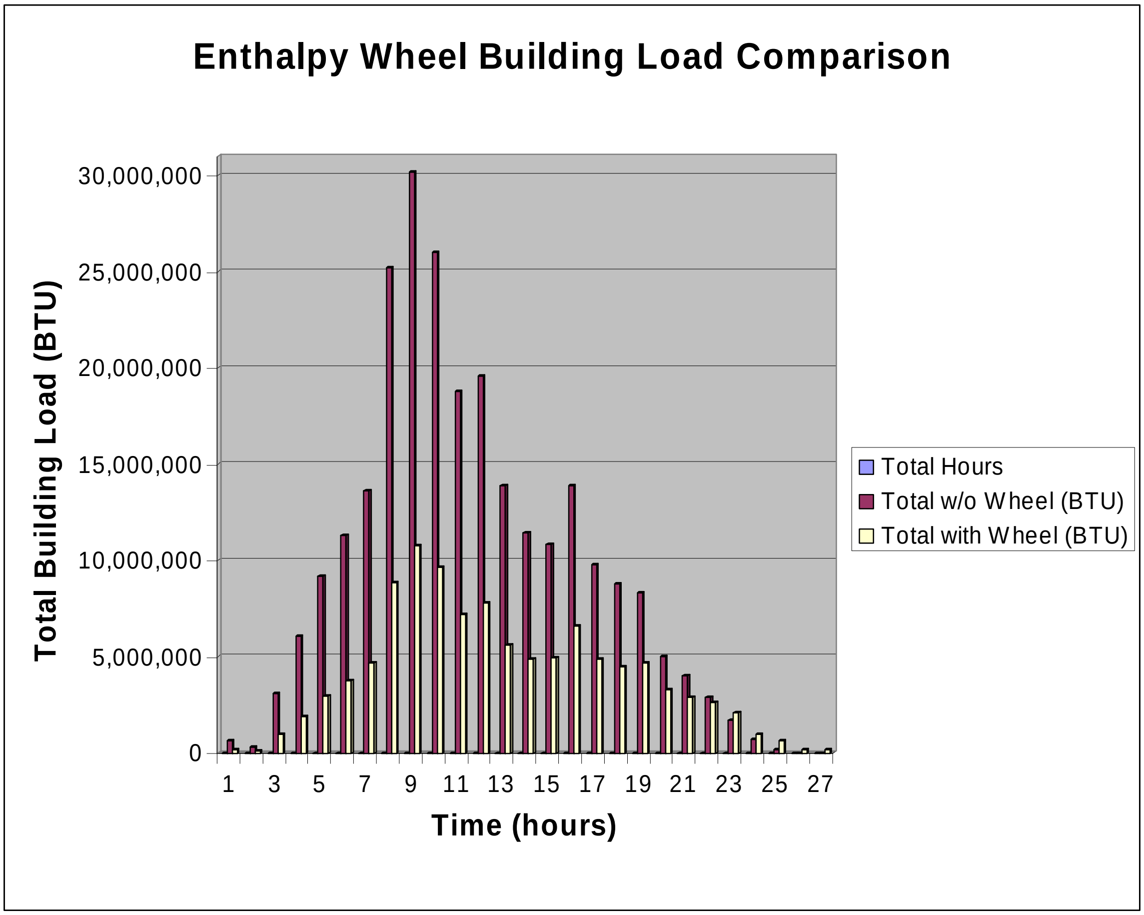

Figure 11 – Enthalpy Wheel Energy Savings

The installation of the enthalpy wheel, over the one year period, was found to reduce the building load 147,782,935 BTU. From an energy standpoint, this is a 43,300 KWH savings. With the utility rate of $0.1/KWH, $4,300 will be saved in the hospital's operating costs for one year. The equations used for this calculation are as follows:

Without the wheel:

Q_S (BTU) = 1.08 x SCFM x (T_1 – 55^{o}F) x # hours (Sensible Load)

Q_L (BTU) = 0.68 x SCFM x (W_1 – 65 gr/lb) x # hours (Latent Load)

Q_T (BTU) = Q_S + Q_L (Total Load)

With the wheel:

Q_S (BTU) = 1.08 x SCFM x (T_2 – 55^{o}F) x # hours (Sensible Load)

Q_L (BTU) = 0.68 x SCFM x (W_2 – 65 gr/lb) x # hours (Latent Load)

Q_T (BTU) = Q_S + Q_L (Total Load)

Energy Saved:

$Q_{(energy\ saved)}$ (BTU) = Q_T (Without the wheel) – Q_T (With the wheel)

Cost Savings With Enthalpy Wheel:

Cost = $Q_{(energy\ saved)}$ (BTU) x (1 KW / 3413 BTU) x ($0.1 / KW)

A Closer Look at Enthalpy Wheel Savings

The enthalpy wheel preconditions the outdoor air ahead of the cooling coil. Instead of the original temperature of 95^{o}F coming in contact with the cooling coil, a lower temperature will be present after going thru the enthalpy wheel. The wheel efficiencies (84.1% sensible and 82.1% latent) will determine these new air temperatures. For a more clear representation of the benefits of having the smaller temperature differentials for the sensible loads and the smaller relative humidity ratio differentials for the latent loads will be presented in the following example calculation. The calculation was done for the 157.3 gr/lb humidity ratio midpoint bin. The desired supply air conditions for the system are 55^{o}F and saturated, yielding a humidity ratio of 65 gr/lb.

Without the wheel:

Q_S (BTU) = 1.08 x SCFM x (87.6^{o}F – 55^{o}F) x 2 hrs = 222,514.56 BTU

Q_L (BTU) = 0.68 x SCFM x (157.5 gr/lb – 65 gr/lb) x 2 hrs = 397,528 BTU

Q_T (BTU) = 222,514.56 BTU + 397,528 BTU = 620,042.56 BTU

With the wheel:

Q_S **(BTU) = 1.08 x SCFM x (74.4^{o}F – 55^{o}F) x 2 hrs = 132,416.64 BTU**

Q_L **(BTU) = 0.68 x SCFM x (76.2 gr/lb – 65 gr/lb) x 2 hrs = 48,133.12 BTU**

Q_T **(BTU) = 132,416.64 BTU + 48,133.12 BTU = 180,549.76 BTU**

Just from the results of one bin, it is evident that the smaller temperature differentials for the sensible load, and the smaller humidity ratio differentials for the latent load provide a very significant reduction in the building's total load while using the enthalpy wheel. See Appendix 4 – Enthalpy Wheel Calculations for the excel spreadsheet containing all of the calculated values.

5 – New Air Distribution Design:

The new VAV system installed in Calvert Memorial Hospital was designed with the appropriate ductwork and air distribution equipment. Supply, return, and exhaust diffusers were selected from the Titus catalog, taking into consideration the following criteria: Appropriate noise criteria ratings (NC), patient comfort, and suitable air mixing.

The NC (Noise Criteria) ratings for hospital patient rooms should range between 25dB - 30dB. In the design of this system an NC rating of 25 dB was chosen for the supply diffusers, and an NC rating of 30 dB was chosen for the return diffusers. These ratings are used in design to ensure the diffusers will not make excess noise when distributing air to the rooms.

Air throws are also important when designing the new system. According to the Waterloo Air Products Air Diffusion Technical Manual, the term "air throw" can be defined as the forward travel of a jet to the point where the maximum velocity has decayed to a nominated terminal velocity. The Titus catalog verifies the appropriate throw distances that need to be associated with the selected diffusers.

The patient room supply diffusers will be placed far enough away from walls or other obstructions to prevent unnecessary drafting on the room occupants. The diffuser throw patterns also create the proper air circulation throughout the room to enhance the benefits of the UV fixtures. The relation between the air circulation and the fixture installation will be further explained in the UVGI Layout section of this report.

Below are the typical duct layouts of the rooms. Note that only the 2nd and 3rd floor plans are shown. The 4th and 5th floors are typical of the 3rd floor.

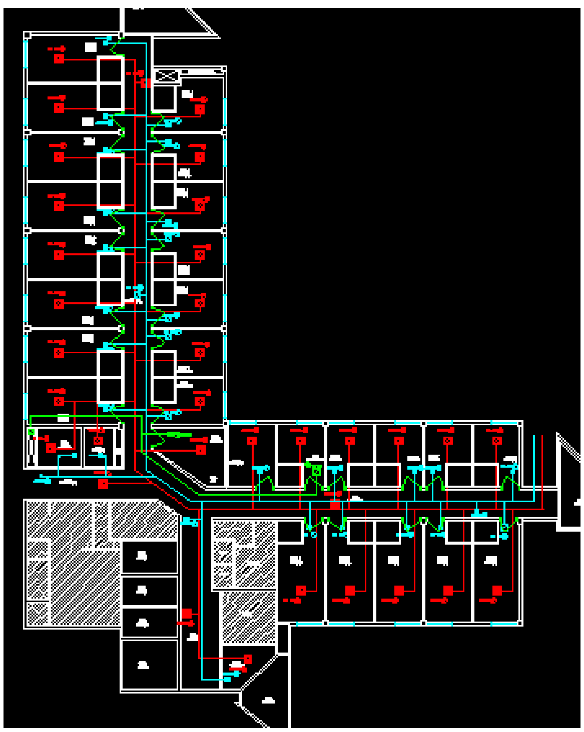

Figure 12 – 2nd Floor Plan

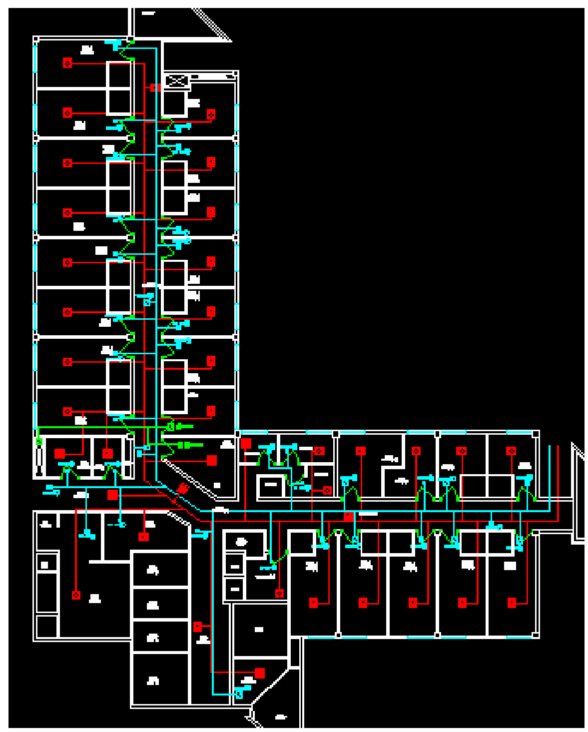

Figure 13 – 3rd Floor Plan (4th & 5th)

6 – Ultraviolet Germicidal Irradiation:

UVGI (Ultraviolet Germicidal Irradiation) is becoming more common in hospitals, clinics, laboratories, and industry. Even the Center for Disease Control recommends using UV lamps for their germicidal effects. But UVGI systems are still a very complicated technology. The calculations and programs that need to be used to determine the accurate airflows, kill rates, and fixture installations are very complex and time consuming and often show varying results. In this report, Calvert Memorial Hospital will be compared to other buildings (with similar construction characteristics) that use the UVGI systems. The results from these similar buildings will be related to Calvert and used for the determination of the hospital's design parameters. The results from using these comparison techniques will probably be very similar to the results gotten by using the complex equations and programs. To allow more time for exploring the actual design of the system, relating the studies of the similar buildings seemed to be the best course of action.

The following criteria will be considered in determining the UV design: building ventilation, safety considerations, occupancy patterns, existing structural limitations, cost, and maintenance. With the for-mentioned guidelines and the help of the Lumalier™ UV manufacturing company, the appropriate fixtures were chosen. Ultraviolet Germicidal Irradiation corner mounted fixtures were picked to be installed in the patient rooms of the 2^{nd} – 5^{th} floor patient tower. These fixtures will sanitize air passing directly through the UV rays by destroying the harmful pathogens that come in contact with them. Some of these pathogens include musty/moldy odors, TB, cold and flu viruses, smallpox, anthrax, and other airborne diseases.

UVGI Layout

The following drawings show the typical layout of the UVGI fixtures in the patient rooms. The top picture shows a typical room with one fixture, and the bottom picture shows a typical patient room with two fixtures.

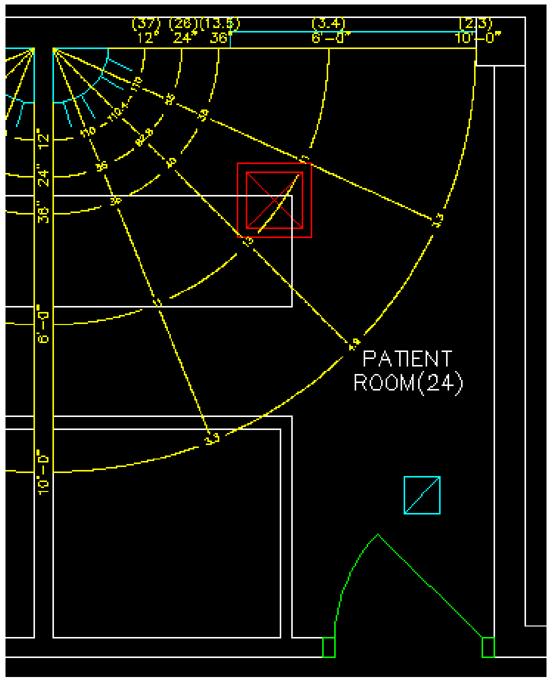

Figure 14 – One UVGI Fixture

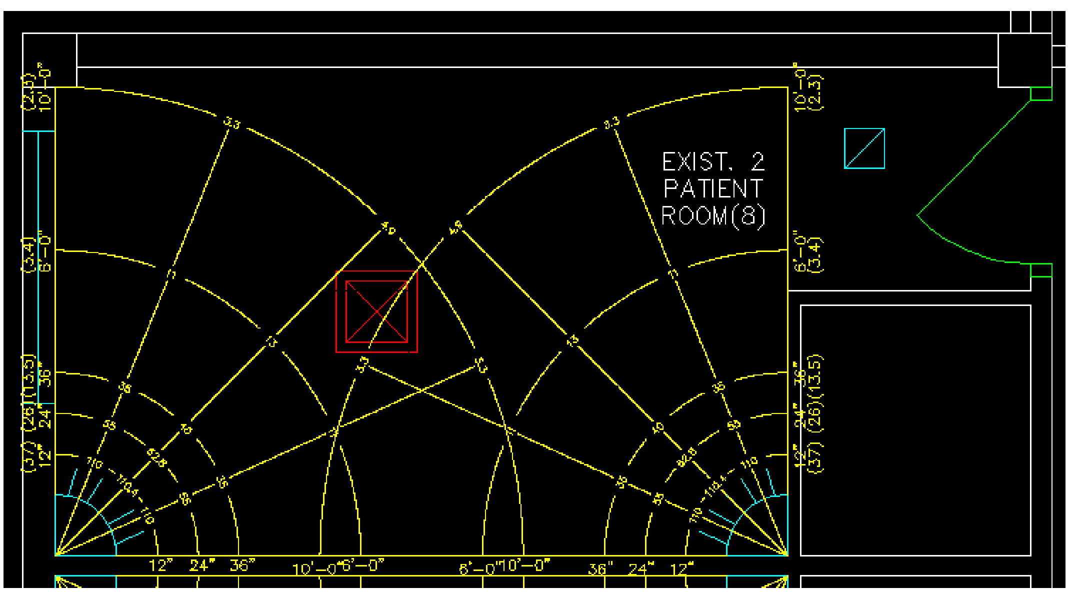

Figure 15 – Two UVGI Fixture

In the beginning, there were two kinds of UV fixtures considered for installation; wall mounted and corner mounted. With the wall mounted fixtures, the possibility of overcrowding could occur due to the complicated equipment layouts above the patient beds. The use of the corner mounted fixtures would avoid this problem of over-crowding. After careful consideration, the corner mounted fixtures were chosen.

In designing the spaces for the UVGI fixtures one of the first items to consider is the ceiling height. The minimum ceiling height for a room with UVGI is eight feet. In the design of Calvert Memorial Hospital, the fixtures will be installed seven feet above the floor level. This ensures that the radiation is not at the eye level of the room occupants. UV levels at six feet above the floor will be checked to make sure proper UV-C levels are in the six foot range. More about the UV testing and maintenance will be explained in the Lighting/Electrical Breadth Testing and Maintenance section.

The next design parameter to take into consideration is the appropriate air movement through the rooms. The air distribution patterns must be carefully arranged to maximize the efficiency of the UVGI fixtures. The placement of supply diffusers (drawn in red) and return diffusers (drawn in blue), and the intensity distribution (drawn in yellow) are very important. The air diffusers will be strategically placed so the supply grilles effectively circulate the air across the UV spread. The return grilles will be placed far enough away from the supply diffusers to even out the air movement through the room. The intensities of the fixtures, which will be described in the next section, will be used to find the survival fractions of the airborne contaminants at particular locations throughout the room.

The CM-218 fixture's nominal UV wattage was a factor in creating the room layout design. The selection of the CM-218 36W corner mounted UV fixtures (shown in blue) came from Mr. Charles Dunn of Lumalier™. Lamp and fixture technical information is provided in the Upper Room Irradiation Fixtures section of the Lighting/Electrical Breadth portion of this report. In many cases, the rule of thumb for fixture placement is approximately 30W per 200 ft^2 of floor area. This was also the recommendation from Mr. Dunn of Lumalier™. The areas of Calvert Memorial Hospital's patient rooms range from 288 ft^2 to 192 ft^2; therefore, in the patient rooms with over 200 ft^2, two corner mounted fixtures were used instead of one.

Survival Fractions of UVGI

Microorganisms exposed to UVGI experience an exponential decrease in population. The single stage exponential decay equation for microbes exposed to UV irradiation is as follows:

$$\mathbf{S = e^{-kIt}}$$

Where S is the surviving fraction of the initial microbial population, k = standard rate constant ($cm^2/\mu J$), I = UV Intensity ($\mu W/cm^2$), t = time of exposure (seconds), and 1 μJ = 1 μW-s.

The survival fractions of four common airborne contaminants were calculated in this report to determine the most effective placement and use of the UVGI fixtures in the rooms. The standard rate constants (k-values) were taken from Table 1 of The Mathematical Modeling of Ultraviolet Germicidal Irradiation for Air Disinfection paper. See Appendix 5 – Rate Constants of Respiratory Pathogens. The examined time periods of exposure ranged from 0 to 4000 seconds. And the lamp intensities were given by the Lumalier™ manufacturers cut sheet for the CM-218 corner mounted fixtures. Figure 16 – UVGI Fixture Intensities shows the intensities (numbers in red) of the UV at certain distances from the fixture.

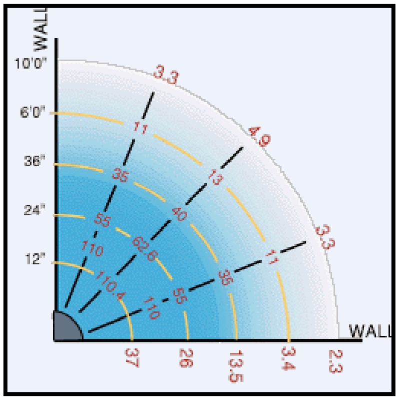

Figure 16 – UVGI Fixture Intensities

These intensities are labeled at distances of 12", 24", 36", 6'0", and 10'0" from the source. The yellow arcs represent the boundaries of each intensity distance. These arcs are labeled to show the different intensities at the respective arc locations, specifically where the UV rays overlap. In these cases the intensities are added.

The objective of the design is to create a contaminant-free environment. In order to reach this goal, a survival fraction of zero must be achieved for every contaminant tested. This value of zero means the contaminant is efficiently killed by the UV rays. With the fixture's given intensity values, four common microbes will be tested to determine the effectiveness of the UV fixtures. The experiment will also tell how long it will take to kill that particular contaminant. The table below shows the four contaminants that will be tested with their respective k-values and time periods of measurement.

Microorganism	Common Name	k (cm^2/micro W-s)	Time Period (sec)
Bacillus anthracis	Anthrax	0.000031	0 - 4000
Streptococcus pyogenes	Strep Throat	0.001066	0 - 60
Haemophilus influenzae	Flu or Common Cold	0.000599	0 - 1000
Mycobacterium tuberculosis	TB	0.004721	0 - 60

Table 4 – Microorganisms Tested

Bacillus anthracis (Anthrax)

In studying the survival fraction of the Bacillus anthracis microorganism, it was found that from the intensities of 110.4 $\mu W/cm^2$ (the most powerful intensity given from the light) to roughly 35 $\mu W/cm^2$; there was a zero survival rate of the microbe over a time period of 0 - 4000 seconds. This covered a total distance of three feet from the fixture in all directions. From the intensities of below 35 μW/cm^2, the bacillus anthracis was not completely killed. The following graphs show the survival rates the fixture can maintain within each of the studied time periods and specified fixture intensities. As the intensity of the fixture decreases, the chance for extermination of the microorganism in the air decreases as well. It was calculated to take approximately 64,800 seconds (18 hours) to kill approximately all of the contaminant in the air. This was calculated for the worst case scenario of the lowest intensity (2.3 μW/cm^2) at the furthest distance (10 feet) from the wall fixture. Keep in mind, these spores are the most difficult to penetrate with UVGI.

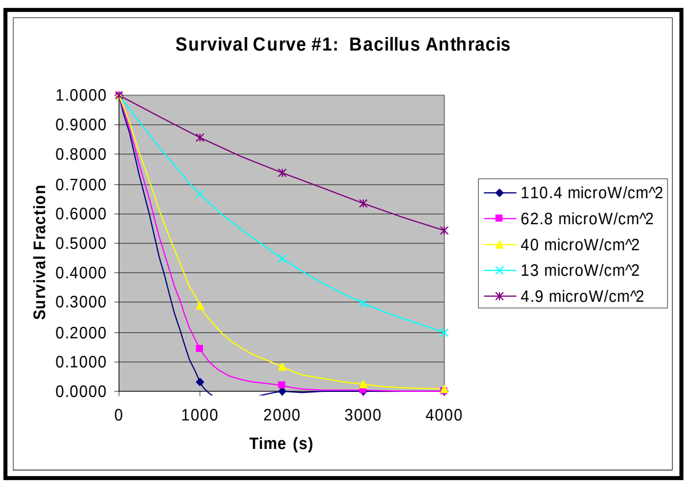

Figure 17 – Bacillus Anthracis Survival Curve #1

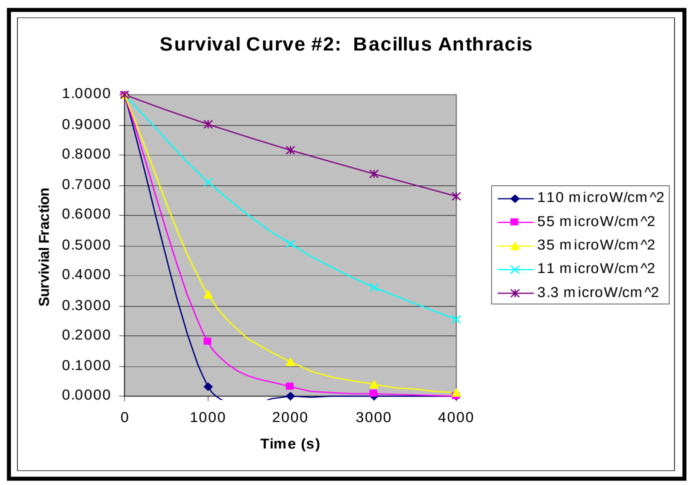

Figure 17.1 – Bacillus Anthracis Survival Curve #2

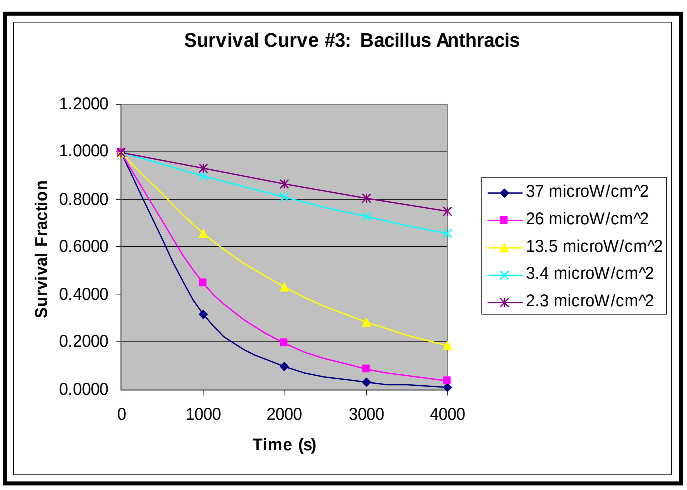

Figure 17.2 – Bacillus Anthracis Survival Curve #3

Streptococcus pyogenes (Strep Throat)

In studying the survival fraction of Streptococcus pyogenes, a time frame of 0 - 60 seconds was considered. This smaller time period was chosen due to the k-value being much larger than that of the bacillus anthrax. In other words, the graphs will give a more clear representation of the survival rates of the microorganisms with the smaller time range. It was found that from the intensities of 110.4 $\mu W/cm^2$ to approximately 40 $\mu W/cm^2$, there was a zero survival rate of the microbe. This covered a total distance of three feet from the fixture in all directions. From the intensities below 40 $\mu W/cm^2$, the streptococcus pyogenes were not completely killed. The following graphs show the survival rates the fixture can maintain within each of the studied time periods and specified fixture intensities. With increasing time, more microorganisms can be killed. But as the intensity decreases, so does the chance for extermination. It was determined to take about 2000 seconds (roughly a half hour) to completely eliminate the contaminant from the room air. This was calculated for the worst case scenario of the lowest intensity (2.3 $\mu W/cm^2$) at the furthest distance (10 feet) from the wall fixture.

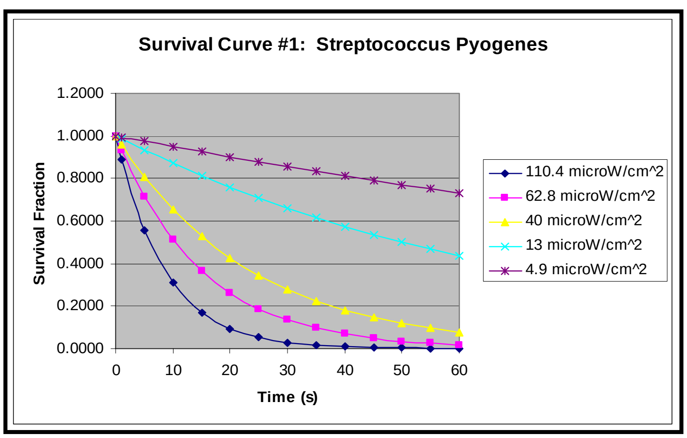

Figure 18 – Streptococcus Pyogenes Survival Curve #1

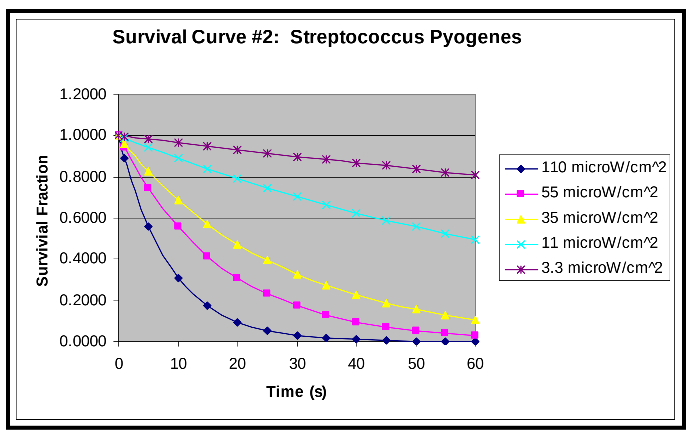

Figure 18.1 – Streptococcus Pyogenes Survival Curve #2

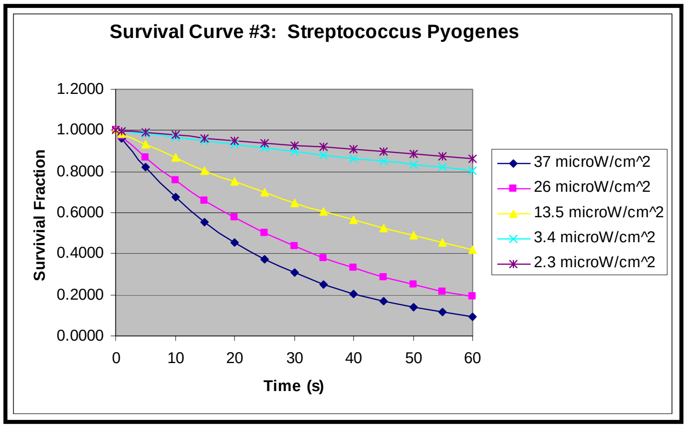

Figure 18.2 – Streptococcus Pyogenes Survival Curve #3

Haemophilus influenzae (Flu or Common Cold)

In studying the survival fraction of Haemophilus influenze, a time frame of 0 - 1000 seconds was considered. This time period was chosen to give a more clearly graphical representation of the survival rates of these microorganisms. It was found that from the intensities of 110.4 $\mu W/cm^2$ to 11 $\mu W/cm^2$, there was a zero survival rate of the microbe. This covered a total distance of six feet from the fixture in all directions. From the intensities below 11 $\mu W/cm^2$, the Haemophilus influenze were not completely killed. The following graphs show the survival rates the fixture can maintain within each of the studied time periods and specified fixture intensities. Just as with the Bacillus anthracis and Streptococcus pyogenes microbes, with increasing time, more microorganisms can be killed, but it depends on the intensity of the fixture at that point of measurement. It was determined to take about 3600 seconds (1 hour) to completely eliminate the contaminant from the room air. This was calculated for the worst case scenario of the lowest intensity (2.3 $\mu W/cm^2$) at the furthest distance (10 feet) from the wall fixtures.

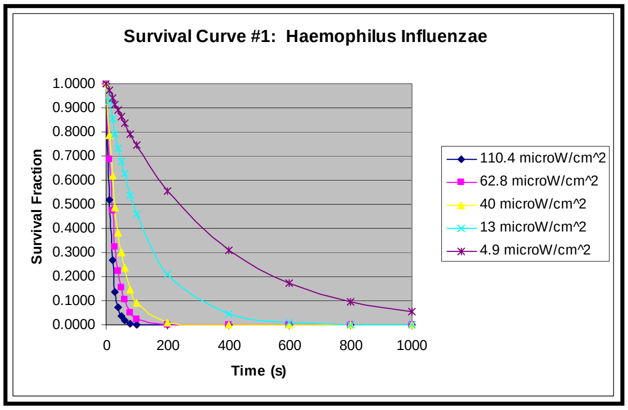

Figure 19 – Haemophilus Influenzae Survival Curve #1

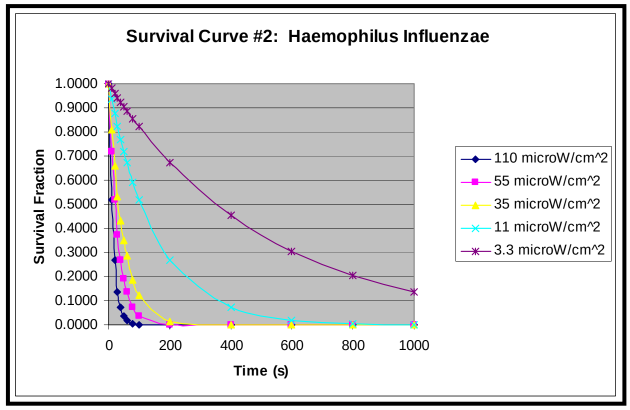

Figure 19.1 – Haemophilus Influenzae Survival Curve #2

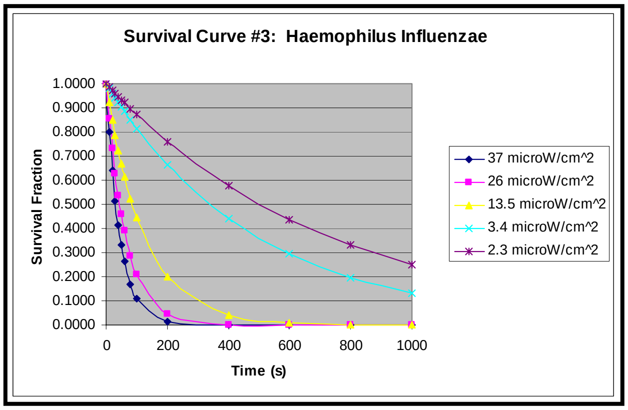

Figure 19.2 – Haemophilus Influenzae Survival Curve #3

Mycobacterium Tuberculosis (TB)

In studying the survival fraction of Mycobacterium tuberculosis, a time frame of 0 - 60 seconds was considered. This time period was chosen to give a more clearly graphical representation of the survival rates of these microorganisms. It was found that from the intensities of 110.4 μW/cm^2 to 13 μW/cm^2, there was a zero survival rate of the microbe. This covered a total distance of six feet from the fixture in all directions. From the intensities below 13 μW/cm^2, the Mycobacterium Tuberculosis was not completely killed. The following graphs show the survival rates the fixture can maintain within each of the studied time periods and specified fixture intensities. Again, with increasing time, more microorganisms can be killed, but the intensity of the fixture at that point of measurement is a key factor. It was determined to take about 480 seconds (8 minutes) to completely eliminate the contaminant from the room air. This was calculated for the worst case scenario of the lowest intensity (2.3 μW/cm^2) at the furthest distance (10 feet) from the wall fixture.

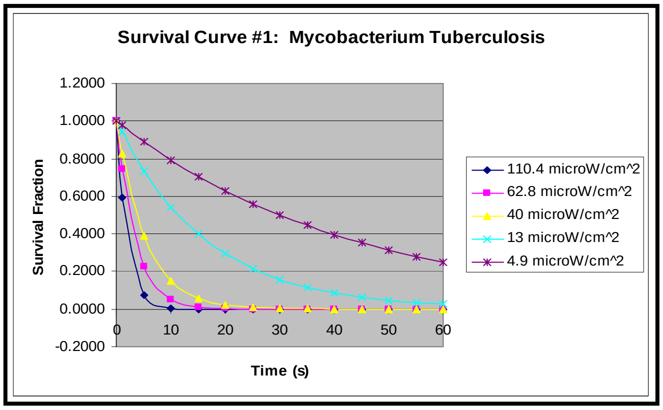

Figure 20 – Mycobacterium Tuberculosis Survival Curve #1

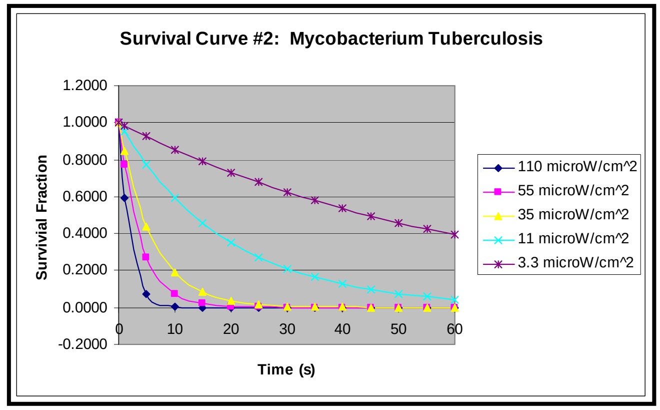

Figure 20.1 – Mycobacterium Tuberculosis Survival Curve #2

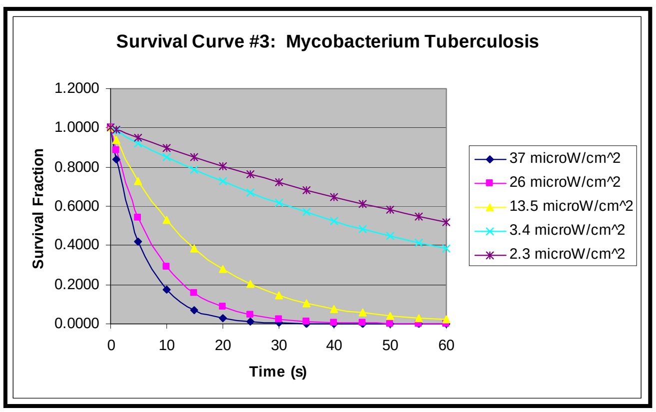

Figure 20.2 – Mycobacterium Tuberculosis Survival Curve #3

Survival Fractions of UVGI Conclusions

The survival fractions of the four common microorganisms were computed due to the fixture specified intensities, the studied exposure periods, and the corresponding standard microbe rate constants. The results varied for each microorganism due to the many differences in the factors just mentioned. Since the survival fraction equation shows a negative exponential curve, it is clear to see that the larger the multiplied k (rate constant), I (intensity), and t (time) components, the lower the survival fraction. For example, microbes such as Bacillus anthracis have a small rate constant ($0.000031\mu W/cm^2$), while the Mycobacterium tuberculosis microbes have a large k-value ($0.004721\mu W/cm^2$). With the time and intensity quantities held constant, the Mycobacterium tuberculosis would have a much lower survival fraction meaning more of the contaminant would be killed.

The results of this experiment suggested that over a time frame of 0 - 4000 seconds, the rated intensities of the fixtures proved to be adequate in killing off most of the harmful contaminants. In some cases, the microbes took longer to completely be eliminated. Bacillus anthracis spores are the most difficult to penetrate with UVGI; therefore, more time was needed at the given intensities to sufficiently rid the air of these microbes. See <u>Appendix 6 – Survival Fractions of Common Contaminants</u> for the excel spreadsheets involving the survival fraction calculations.

Airflow Rates & UVGI

In an article from <u>Infection Control Today</u> written by David R. Linamen, some very interesting observations were made. Recent research was conducted at the National Institutes of Health (NIH) by Farhad Memarzadeh, MD, and Andrew Manning, MD. The study indicated that the number of viable TB bacteria in a patient room can be significantly reduced by implementing the proper ventilation and UVGI lights. It was also proved that both the first cost and operating costs of UVGI are significantly less than the associated cost with increasing the room airflow rates.

The exact calculation for determining the efficiency of the UVGI lights is very complicated and is dependent on a number of things. Some of these characteristics include the building's ventilation system, safety concerns, occupancy patterns, existing structural limitations, cost, and maintenance.

To get a rough idea of a UVGI system energy and cost savings, the study performed by Dr. Memarzadeh and Dr. Manning will be referenced. The study evaluated 40 different room configurations and three different combinations of lamp intensity and location. The room air changes were increased from 6 ACH to 16 ACH when UVGI was not used. This resulted in a 30% reduction in the viable TB bacteria in the room. Also, increasing the number of air changes to the rooms failed to provide a meaningful reduction of infectious particles in the rooms. When UVGI was used, at 6 ACH, there was a 68% decrease in the number of viable bacteria.

A suggested airflow rate to each patient room of Calvert Memorial Hospital is 6 air changes per hour. This means the quantity of air equal to the volume of the room is supplied and/or exhausted every 10 minutes. Ideally, 6 ACH are chosen when designing these spaces to ensure the room occupants are not exposed to strong air currents or unnecessary drafting. If the airflow rates per hour (ACH) of the Calvert Memorial Hospital patient rooms are related and compared to the results of the study done by Dr. Memarzadeh and Dr. Manning, many interesting conclusions can be made. Just in looking at the patient rooms, the new airflow of 16 ACH without UVGI would create an airflow of 46,966 cfm and only have 30% reduction in infectious particles. With the original 6 ACH airflow pattern and added UVGI fixtures, the space airflow requirements would be 24,930 cfm and have roughly a 68% reduction in the infectious airborne particles. In this case, by adding UVGI lights and keeping the 6 ACH airflow rates, 1,779,991,453 BTU would be saved over the course of one year.

Floor	CFM w/UVGI	CFM (16 ACH) w/o UVGI	Difference (CFM)
2nd	6,735	12,151	5,416
3rd	6,065	11,605	5,540
4th	6,065	11,605	5,540
5th	6,065	11,605	5,540
Total	**24,930**	**46,966**	**22,036**

Table 5 – Airflow Differences with and without UVGI

Looking at things from an energy standpoint, this is 521,533 KWH. With the utility rate of $0.1/KWH, the cost savings will end up being $52,153 for one year.

Floor	CFM w/UVGI	CFM w/o UVGI	Difference (CFM)	Btu w/UVGI 1: Year	Btu w/o UVGI 1: Year	Difference (BTU): 1 Year	Energy (KWH)	Cost Savings ($)
2nd - 5th	24,930	46,966	22,036	2,013,759,840	3,793,752,293	1,779,992,453	521,533	$52,153

Table 6 – UVGI Yearly Load Savings

The above table illustrates the difference in airflows to the rooms with and without the UVGI lights. The fixtures cost roughly $450 per fixture, so in installing 141 fixtures in the 2nd – 5th floor patient tower, a total cost of the fixtures would be $63,450. (See Appendix – 8 UVGI Electrical Information & Calculation Tables). In the following section, the total costs of the building systems will be evaluated to determine if there is an appropriate payback period.

7 – New Mechanical System Cost Analysis:

In determining how beneficial the suggested systems would be, a cost analysis was done. First, the cost for the new air handling unit was computed. Then the UVGI fixtures and enthalpy wheel costs were determined. By totaling these items, a total first cost of $364,925 was established.

System First Cost	Cost ($)
AHU	$298,475
UVGI fixtures	$63,450
Enthalpy wheel	$3,000
Total Cost	**$364,925**

Table 7 – System First Cost

Energy and operating costs were then calculated. Over the course of one year the energy savings, when using the enthalpy wheel were determined to be $4,330. The energy savings from the 6 ACH airflow rate instead of 16 ACH airflow rate came out to be $52,153. Finally, the total savings in operating costs for one year were determined to be $56,483.

System Savings Per Year	Cost ($)
EW	$4,330
Airflow (6 ACH vs.12 ACH)	$52,153
Total Operating Cost Savings	**$56,483**

Table 8 – System Cost Savings For 1 Year

After establishing the new system's first cost of $364,925, and knowing the savings for one year in energy operating costs ($56,483), the system was found to have a total payback period of approximately 6.5 years.