Influence of External Factor on Refrigerating Effect of the Air Conditioner

Lizhe Zhang

Shanghai High School, Shanghai, China

Keywords: Thermodynamic Optimization, Vapor Compression Air-Conditioner, Interference of Light, Solar Radiation

Abstract: from Qualitative to Quantitative, the Correlation is Determined in the Paper between the Cooling Power of Vapor Compression Air-Conditioners for Household and Various Living Environmental Parameters, by Theoretical Derivation and Thermodynamic Model Simulation. on Account That Room Heat Mainly Comes from Solar Radiation, Factors Such as the Latitude of a Room, the Orientation of the Windows Facing, and Different Dates in Summer Greatly Impact the Cooling Efficiency of Air-Conditioners in the Room. Here, the Influences on the Air Conditioning Refrigeration That Were Imposed by the Daily Variation and Annual Variation of Solar Radiation Received by a Room as Well as the Thermodynamic Parameters of a Room (Such as Specific Heat and Total Thermal Resistance) Were Analyzed in a Systematical Way. Moreover, We Found Window Glass Remarkably Impairing Solar Radiation When in Analysis Using a Multi-Beam Interference Model. on the Specific Influencing Modes and Degree of Various External Factors on the Air Conditioning Refrigeration Efficiency, the Qualitative and Quantitative Investigations Involved Will Benefit the Efficient Green Utility of Refrigeration Air-Conditioning.

1. Introduction

Air Conditioners Are One of the Household Appliances Essentially Important to the Modern Life of Residents. Their Advent and Prevalence Have Significantly Lifted Up people's Quality of Life. with Greenhouse Effect Constantly Aggravating, Refrigeration and Air-Conditioning Equipment Has Become a Boon for the Mass in Blistering Summer Days. The Refrigeration Air Conditioners Used for Ordinary Households and Automobiles Are All Vapor Compression Air-Conditioners (Vcac). in Their Practical Service, Their Cooling Efficiency and Performance Are Subject to a Variety of Environmental Factors and Human Factors to a Different Extent. One of the Key Factors Affecting the Temperature of a Room is the Total Amount of Solar Radiation Coming into the Room Eventually. Besides, the Actual Heat Insulation of Curtains and Rooms Are Two Artificial Factors Influencing the Indoor Temperature in Real Life. We Hope to Determine the Relation between the Refrigeration Power of Air Conditioners and Different Environmental Parameters from Qualitative Level to Quantitative Level, by Thermodynamic Modeling and Theoretical Calculation. Meanwhile, Influences That Different Factors Made on the Accuracy of the Model Were Also Fully Considered in the Modeling Process. Together, It Will Be Beneficial to the Green Use of Refrigeration Air-Conditioners in a Manner of Low Energy Consumption and High Efficiency.

2. Modeling

To figuring out the refrigeration process of a room, we set up thermodynamic equations to model and quantify the process. The heat input mostly sources from solar radiation when a room is in refrigeration. The thermodynamic parameters of the room are serving to be the internal influencing factors. In quantifying the power of solar radiation, we were first to make clear its direction, especially its angle with the normal direction of windows. Also, we noticed the possible strong weakening effect of windows on solar radiation. Holding the thought of from local to whole thought, I first constructed a Sun-Earth-Building spatial model. Then, I built up a glass reflection factor model, from which the final mathematical expression of solar power was derived. At last, a thermodynamic model was structured to describe the refrigeration process of air conditioners.

DOI: 10.25236/acete.2019.024

Firstly, I assumed the subject studied to be the solar radiation in sunny days, that is, approximately considering no loss to be generated when the solar radiation was passing through the Earth's atmosphere. I also took out of account the heat supplies other than solar radiation. In the thermodynamic model of a room, I only took the heat conduction into consideration while neglecting the presence of air ventilation and outward heat dissipation of heat radiation.

2.1 The Sun-Earth-Building Spatial Model

First of all, we quantitatively analyzed the power of solar radiation received per unit area of a window in a house, by establishing a sun-ground-building spatial model. The relevant parameters are defined as follows:

t_0:beginning of a year
t_1:days from the be ginning of the year
t_2:Time and hours on that day
P_s:solar constant,taken as 1367W
Ψ:Precession angle
α:the obliquity of the ecliptic
θ:dimension
Φ:the position of the building relative to the Erth axis angle
φ:the intersection angle between the noemal direction of a window and the due north
i_0:the intersection angle between the solar radiation and the atmosphere noemal
i_1:the incident angle of solr radiation entering a window
P_n:the power of solar radiation received on perunit area of a window

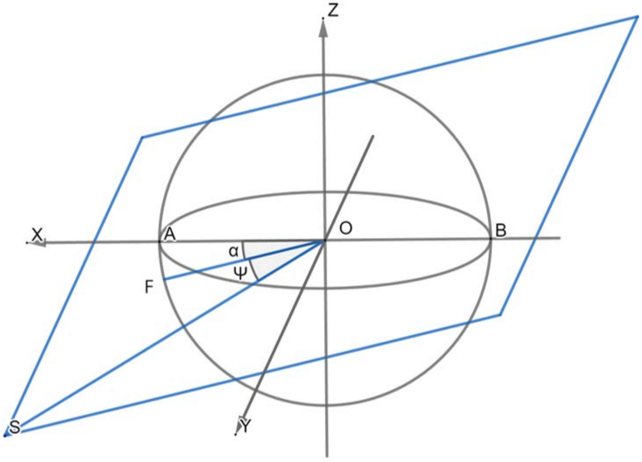


Figure 1. The Sun-Earth coordinate system

The bigger ball is the Earth, established with x, y, z coordinate axis shown as the Figure. The blue plane is the ecliptic plane, and the black plane is the equatorial plane. Axis y is the intersection line of the equatorial plane and the ecliptic plane. Axis x is a ray on the ecliptic plane and perpendicular to the y-axis. The obliquity of the ecliptic $\angle AOF=\alpha$, and the precession angle $\angle FOS=\Psi$.

Supposed to be pointed out, it was taken on the winter solstice in the Northern Hemisphere when $\Psi=0$,

Thus, it was expressed by t_1 and t_2, as:

$$\Psi = \frac{2\pi}{365}\left(9+t_1+\frac{t_2}{24}\right) \quad (1)$$

The direction of the sun in the coordinate system above:

$$\vec{s} = (\cos(\Psi)\cos(\alpha), \sin(\Psi), -\cos(\Psi)\sin(\alpha)) \quad (2)$$

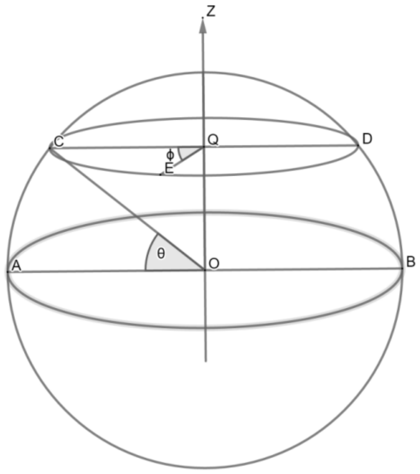


Figure 2: The Earth--Building Coordinate System. the Latitude is $\angle Coa=\Theta$

The bigger ball is the Earth. Point E is where the room is located.
The angular position of the building relative to the earth axis is $\angle CQE = \phi$.

The step function is defined as: $u(x)$

$$= \begin{cases} 1 & , x \geq 0 \\ 0 & , x \leq 0 \end{cases}$$

It is supposed to be pointed out that

$$\phi = -\pi u(\cos\Psi) + \arctan(\tan\Psi \sec\alpha) + \frac{\pi}{12} t_2$$

(3)

Thus,the unit vector in the OA direction is:

$$\vec{a} = (\cos(\theta)\cos(\phi), \cos(\theta)\sin(\phi), \sin(\theta))$$

(4)

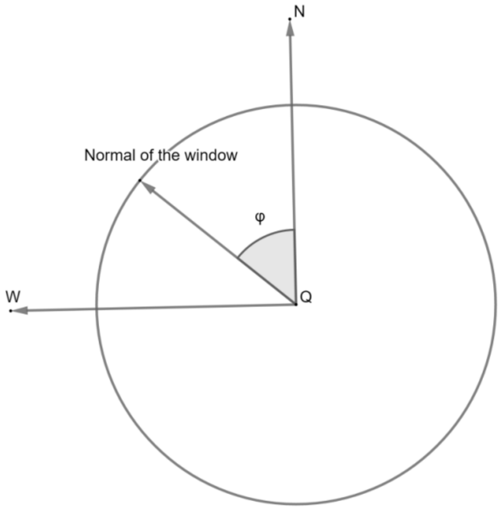


Figure 3: The Model of a Building’s Orientation

ϕ is the angular position the building relative to the earth axis. Point out the orientation, shown in the Figure. N denotes the north of the building, and W denotes the west of the building.

Through observation, the direction unit vectors of the north N and the west W are, respectively

$$\vec{W} = \left(\sin(\phi), -\cos(\phi), 0\right) \quad (5)$$

$$\vec{N} = (-\sin(\theta)\cos(\phi), -\sin(\theta)\sin(\phi), \cos(\theta)) \quad (6)$$

The normal direction of the windows is: $\vec{T}=\cos(\varphi)\vec{N}+\sin(\varphi)\vec{W}$. Bring it into (5) and (6), and following equation can be obtained:

$$\vec{T}=(-\cos(\varphi)\sin(\theta)\cos(\phi)+\sin(\varphi)\sin(\phi),-\cos(\varphi)\sin(\theta)\sin(\phi)-\cos(\phi)\sin(\varphi),\cos(\theta)\cos(\varphi))$$

(7)

Thus, the intersection angle $i_0$of solar radiation and the atmosphere is $\cos(i_0)=\vec{s}\cdot\vec{a}$. Brought in (4) and (7), it turns to be:

$\cos(i_0)=\cos\Psi\cos\alpha\cos\theta\cos\phi+\sin\Psi\sin\phi\cos\theta-\sin\theta\sin\alpha\cos\Psi$ (8)

The incident angle $i_1$that solar radiation entering the window is $\cos(i_1)=\vec{T}\cdot\vec{s}$; brought in (2) and (7), it turns to be:

$\cos(i_1)=-\cos\Psi\cos\alpha\cos\varphi\sin\theta\cos\phi+\sin\varphi\sin\phi\cos\Psi\cos\alpha-\cos\varphi\sin\theta\sin\phi\sin\Psi-\cos\phi\sin\varphi\sin\Psi$

(9)

From (3) and (1), following equation can be obtained:

$$\Psi=\frac{2\pi}{365}\left(9+t_1+\frac{t_2}{24}\right),\ \phi=-\pi u(\cos\Psi)+\arctan(\tan\Psi\sec\alpha)+\frac{\pi}{12}t_2$$

Then, the radiation power P_n received per unit area of a window can be written as

$P_n=P_s\cos i_1\,u(\cos i_1)u(\cos i_0)$ (10)

From Eq(10), it can be harvested that the radiation of sunlight received per unit area at night is zero.

2.2 Glass Reflection Factors

In Section 2.1, we established the relationship between the solar radiation received by the unit area of the window and the solar constant and the direction of solar light propagation. On this basis, we further consider the effect of glass refraction on the total projected power that ultimately enters the room. The relevant parameters are defined as follows:

n: the refractive index of window glass

i_2 :the refraction angle of solr radiation entering the glass at the window

R_s:the energy transmission of the s component of solar radiation

(the component perpendicular to the plane of the ray and the normal)

R: the total transmittance of solar radiation

P_T:the total transmission power of solar radiation entering the room

A:the effective transmission area of the window of the room

h:the thickness of window glass

λ:a certain wavelength of solr radiation

From the law of refraction:

$\sin(i_1)=n\sin(i_2)\Leftrightarrow\cos i_2=\sqrt{1-(1-\cos^2(i_1))/n^2)}$ (11)

From the Fresnel refraction and reflection law, the energy reflectance in direction s and p is given as below:

$R_s=\left(\frac{\cos i_1-n\cos i_2}{\cos i_1+n\cos i_2}\right)^2$ (12)

$R_p=\left(\frac{n\cos i_1-\cos i_2}{n\cos i_1+\cos i_2}\right)^2$ (13)

The sun sets off natural lights, and then

$$R=\frac{R_s+R_p}{2}$$

To simplify the calculation,the parame is set as:

$$v=\frac{\cos i_1}{\cos i_2}+\frac{\cos i_2}{\cos i_1},u=n+\frac{1}{n}$$

Bring the parameter in Eq (12) and (13), it can be obtained:

$R=\frac{u^2+v^2-8}{u^2+2uv+u^2}$ (14)

This equation is amazingly simplified.

Based on the multi- beam interference formula, for the light with wavelength λ, there is

$$P_T(\lambda) = P_n(\lambda) \cdot A \cdot \left(1 + \frac{4R}{(1-R^2)} sin^2 \frac{2nh\,cos\, i_2}{\lambda}\right)^{-1}$$

Set the parameter as:

$$\omega = \frac{2n\hbar cos\, i_2}{\lambda}, k = \frac{4R}{1+R^2}$$

Then,$P_T(\lambda) = A \cdot P_n(\lambda)(1 + k\, sin^2\, \omega)^{-1}$

$nh \gg \lambda\ is\ noticed$. That is to say, $\frac{2nh\,cos\, i_2}{\lambda}$ quickly shaking with λ changing. The λ changed quite slightly in a period of $\triangle\, \omega = 2\pi$.

$P_T = \frac{P_n \cdot A}{2\pi} \int_0^{2\pi} \frac{d\omega}{1+k\, sin^2\, \omega} = P_n \cdot A \cdot \frac{1-R}{1+R}$ (15)

Bring Eq(14) into Eq(15), and obtain

$P_T = P_n \cdot A \cdot \frac{uv+4}{u^2+v^2+uv-4}$ (16)

The parameter is reduced to

$$P_T = P_n \cdot A \cdot \frac{(n + n^{-1})\left(\frac{cos\, i_1}{cos\, i_2} + \frac{cos\, i_2}{cos\, i_1}\right) + 4}{(n^2 + n^{-2}) + (n + n^{-1})\left(\frac{cos\, i_1}{cos\, i_2} + \frac{cos\, i_2}{cos\, i_1}\right) + \left(\frac{cos\, i_2}{cos\, i_1}\right)^2 + \left(\frac{cos\, i_1}{cos\, i_2}\right)^2}$$

(17)

2.3 Thermodynamic Model of Air Conditioning Refrigeration

By determining the total projected power P_T of solar radiation entering the room and the heat transfer coefficient κ of the room, we can preliminarily build up the thermodynamic model of room air conditioning refrigeration. The relevant parameters are defined as follows:

P_T:the power of radiation entering the room through the glass

T:the room temperature

T_0:the outdoor temperature

C:the energy required to raise the indoor temperature T by 1K

K:the heat transfer coefficient, that is, the ratio of heat dissipation power to temperature difference T-TO.

P0:the rated input electric power of air conditioner

η:the energy efficiency ratio in the second assumption. that is, the ratio of the air conditioning cooling power to the

P1:the cooling power actually provided by the air conditioner

The equation of changes in the room temperature is built as

$CdT = (P_T - \kappa(T - T_0) - P_1)dt$ (18)

When the air conditioner is off or being powered on, there is

$P_T = \kappa(T_{t=0} - T_0)$ (19)

Generally speaking,

$P_1 = \eta P_0$ (20)

η refers to the so-called “energy efficiency rate”, that is, the ratio of the actual output power of the air conditioner to the input electric power. Often marked on the nameplate of the air conditioner, it is an important indicator of air conditioning efficiency.

Combine Eq (18) and (20)

$$\begin{cases} P_1 = \eta P_0 \\ CdT = (P_T - \kappa(T - T_0) - P_1)dt \end{cases}$$

$$\Leftrightarrow CdT = (P_T - \kappa(T - T_0) - \eta P_0)dt$$

Set x= $T - T_0$, and there is

$x = \frac{1}{\kappa}\left[(\eta P_0 - P_T + \kappa x_0)e^{\left(-\frac{\kappa}{C}t\right)} - \eta P_0 + P_T\right]$ (21)

According to Eq(19), Eq(21) is converted into

$$T = T_0 + \frac{1}{\kappa}\left(\eta P_0 \cdot e^{\left(-\frac{\kappa}{c}t\right)} - \eta P_0 + P_T\right) \quad (22)$$

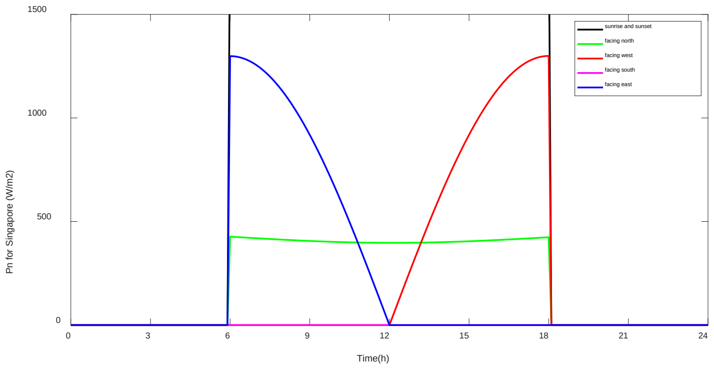
3. Results and Discussion

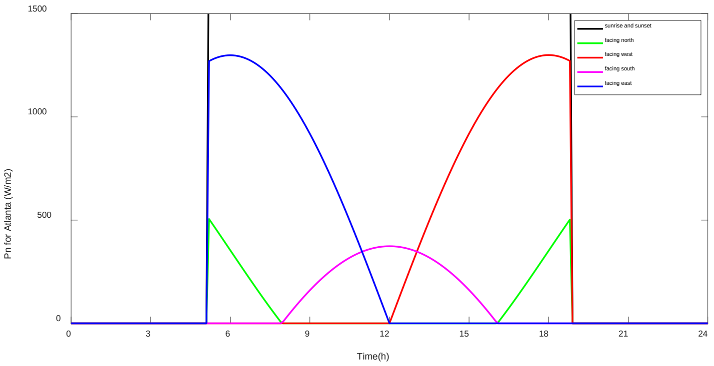
3.1 Solar Radiation Power P_n Acceptable for Per Unit Area of a Window

Known from E_q (10), the maximum solar radiation power acceptable for per unit area of a window is $1453W/m^2$, and the minimum is 0.

First of all, we discussed the effect that the latitude and facing direction of a room imposes on the solar radiation power P_n acceptable for per unit area of a window. Taking August 1, a day in summer in the Northern Hemisphere, the obliquity of the ecliptic on this day was $\alpha = 23^\circ 26'$. Three cities (Singapore, Atlanta and Beijing) were chosen. They are located about $1^\circ 20'$ $(Singapore), 33^\circ 46'$ $(Atlanta), 39^\circ 54'$ $(Beijing)$ in northern latitude. The intersection angles φ of window orientations in these three cities and the normal north were $0, \frac{\pi}{2}, \pi, \frac{3\pi}{2}$, respectively. The image that their P_n changes with time on August 1 is made out.

As shown in Figure 4, the eastward-facing rooms in all regions are under sunlight in the morning. The sun shine peaks shortly after sunrise and falls down to 0 around noon. The west-facing rooms bath in sunshine at afternoons and evenings. Their sunshine summits the top shortly after sunset and is 0 near noon. In the mid-latitudes, the south-facing rooms enjoy sunshine for longer time, with an averagely lower intensity. The sunshine serves from 7 or 8 o'clock in the morning to 5 or 6 o'clock in the evening. On contrast, the north-facing rooms can only bath in sunshine within the short time after sunrise and before sunset. For this reason, the Chinese consider it better to sit in the north and face the south. This idea was reasonable in days not hot in the ancient era. But in the summer of regions close to the equator in the Northern Hemisphere, the south-facing rooms have no luck to bath in sunshine, and the sunshine for the north-facing rooms are more even and lower in intensity. It is equivalent to turn upside down the direction in winters in the Northern Hemisphere.





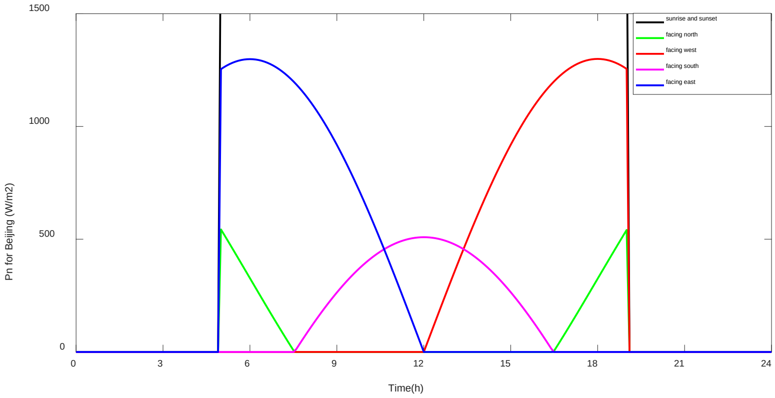


Figure 4: The amount of solar radiation received by a different unit of window in three cities in the northern hemisphere over time on August 1 (a) Singapore; (b) Atlanta; (c) Beijing.

Next, we take the south-facing window as an example to discuss the change in the amount of solar radiation received by the window unit area in Shanghai (latitude 31°) in June July, August, and September (The season when there is air conditioning demand). As shown in Figure 5, the maximum daily solar power appears around noon. As the sun's direct point moves southward, the length and intensity of the sun's illumination rise. But the power is relatively small throughout the summer, no more than $640W/m^2$.

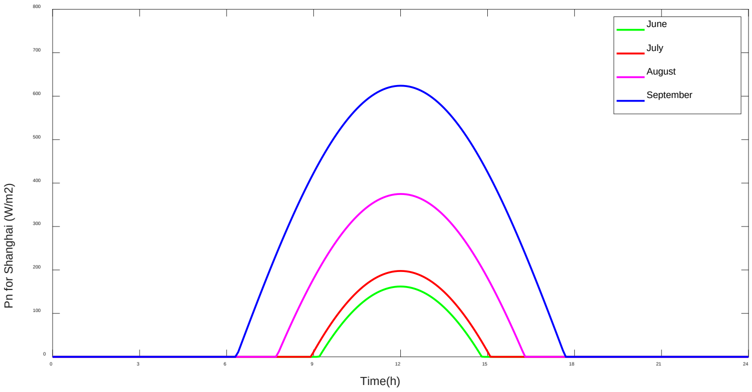


Figure 5. Changes in the Amount of Solar Radiation Received Per Unit Area of a Window Facing the South in Shanghai, the 15th Day of Different Months in summer.

Supposed to be pointed out, the discussion above is only about the P_n. But from the equation (1), it is:

$$P_T = P_n \cdot A \cdot \frac{(n+n^{-1})\left(\frac{cos\, i_1}{cos\, i_2}+\frac{cos\, i_2}{cos\, i_1}\right)+4}{(n^2+n^{-2})+(n+n^{-1})\left(\frac{cos\, i_1}{cos\, i_2}+\frac{cos\, i_2}{cos\, i_1}\right)+\left(\frac{cos\, i_2}{cos\, i_1}\right)^2+\left(\frac{cos\, i_1}{cos\, i_2}\right)^2}$$

The final radiated power also has a coefficient. Set this coefficient to be:

$$\mu = \frac{(n+n^{-1})\left(\frac{cos\, i_1}{cos\, i_2}+\frac{cos\, i_2}{cos\, i_1}\right)+4}{(n^2+n^{-2})+(n+n^{-1})\left(\frac{cos\, i_1}{cos\, i_2}+\frac{cos\, i_2}{cos\, i_1}\right)+\left(\frac{cos\, i_2}{cos\, i_1}\right)^2+\left(\frac{cos\, i_1}{cos\, i_2}\right)^2}$$

As can be seen from Fig. 6, this coefficient μ is very stable when a is small, about 0.9, and suddenly drops after a exceeds 1.

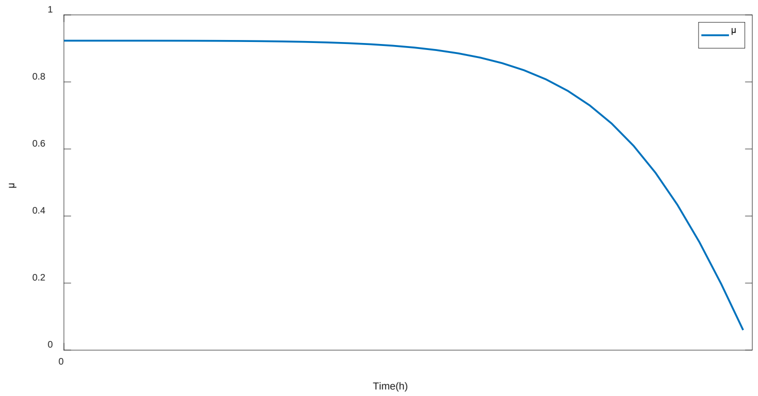


Figure 6: the coefficient μ

Therefore, μ was taken into account. Supposing that the window area is 2 square meters, taking the hottest July 15th and August 15th. It is known from Fig. 7 that the loss due to multi-beam interference is very significant. This is because the south facing window normal has a small angle with the sun, and thus the transmittance is low.

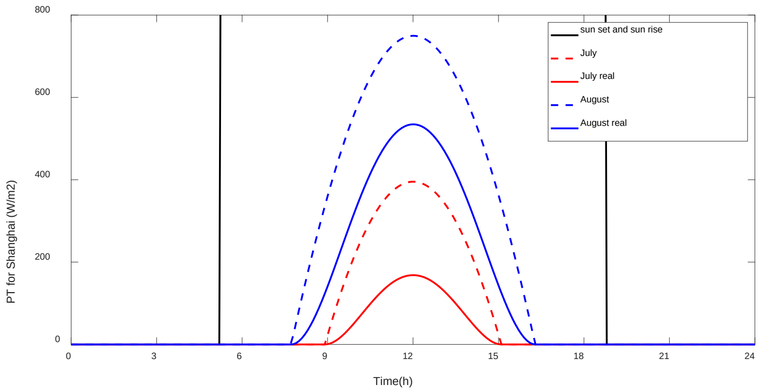


Figure 7: Before and after correction with the coefficient, Shanghai's south facing windows receive changes in solar radiation per unit area of windows in July and August 15. The dotted line is the result of not considering the loss caused by multi-beam interference, and the solid line is the result of consideration.

These data laid the foundation for the discussion of thermodynamic models later.

3.2 Acceptable Solar Radiation Power P_n Per Unit Area of Windows

The rated output power P_0 of the general vertical air conditioner power is between 2000W and 2500W, and the hanging air conditioner is around 1500W. The energy efficiency ratio η is generally between 3 and 3.5.

The heat transfer coefficient κ is relatively large in relation to the room type. If the building is 2 meters high, the window area is 2 square meters, the glass thickness is 1.5 centimeters, and the floor area is 30 square meters, the material is concrete, and the thickness is 0.5m. Then, the calculated result is:

$$\kappa_{\text{concrete}} = 1.74J/K$$

$$\kappa_{glass} = 0.75J/K,$$

$$\kappa = \kappa_{\text{concrete}} \frac{S_{concrete}}{d_{concrete}} + \kappa_{glass} \frac{S_{glass}}{d_{glass}} = 204.4J/K$$

A room with an area of 40 square meters and a height of 2 meters, the air specific pressure heat capacity is about c=$1005J/(kg \cdot K)$ at a temperature of 300K and 1atm.

$$C = \rho V c$$

$$C = \frac{1.29 \cdot kg}{m^3} \cdot 40m^2 \cdot 2m \cdot \frac{1005 \cdot J}{kg \cdot K}$$

By calculation, it is obtained: $C = 1.038 \cdot 10^5 J/K$

According to the above, we take $P_0 = 2000W$ and η=3.3. When the outdoor temperature T_0 is 35 degrees Celsius (T_0=308K), the room air conditioning refrigeration efficiency is affected by the room solar radiation total transmittance P_T, the heat transfer coefficient κ, and the room heat capacity C.

When $\kappa = 200$ and $C = 10^5 J/K$, the air conditioning refrigeration efficiency obtained by Eq (22) is affected by the total solar radiation PT of the room. As can be seen from Fig. 8, the time to reach a suitable temperature of 23 degrees Celsius is 244s, 263s, 288s. In fact, from equation (22), the effect of P_T is to increase by $\frac{P_T}{\kappa}$ celsius as a whole.

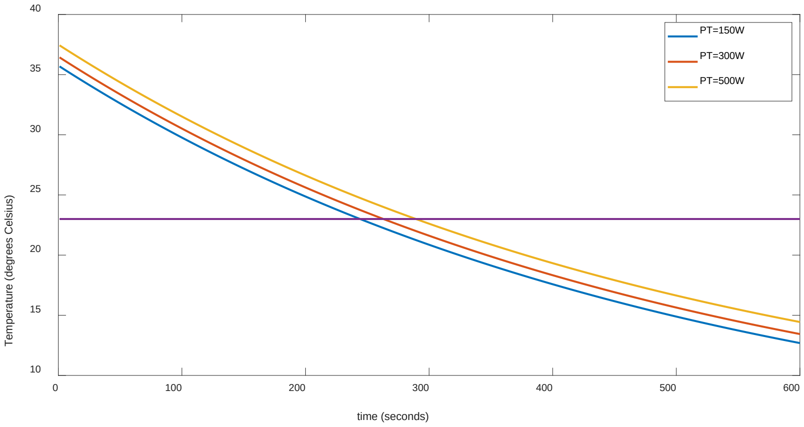


Figure 8: Air Conditioning and Refrigeration Curves Corresponded to the Total Transmitted Power Pt of Different Solar Radiation.

When $C = 10^5 J/K$, $P_T = 500W$, from the equation (22), the influence of room heat insulation effect on air conditioning refrigeration efficiency is known. As shown in Figure 9, the time to reach a suitable temperature of 23 degrees Celsius is 284s, 302s, 407s. The better the insulation, the higher the initial temperature, but the faster the cooling, and finally the shorter the time to reach the proper temperature.

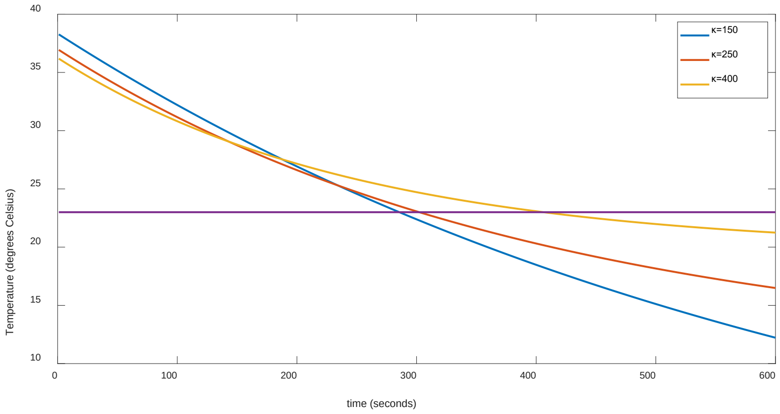


Figure 9: Air Conditioning and Refrigeration Curves Corresponded to Different Heat Insulation Effects.

At last, let's focus on the effect of room size on the refrigeration efficiency of air conditioner. Taking $\kappa = 200$ and $P_T = 500W$, as shown in Figure 10, the bigger the room is, the slower the cooling is naturally.

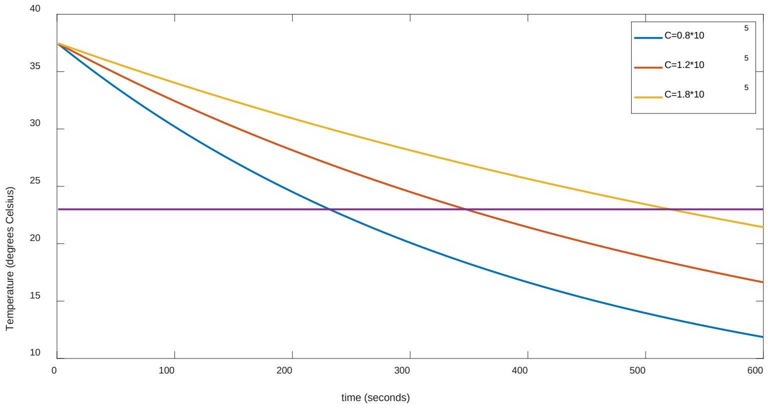


Figure 10: Refrigeration curves for rooms of different sizes.

3.3 Impacts of Other Factors

In addition to the two dominate factors, solar radiation and room heat conduction, there are other external factors. Let's now look at the influences on the cooling efficiency of air conditioning by these factors, such as curtains, atmospheric refraction and absorption.

$$\kappa = 200, \mathrm{P}_T = 500W, P_0 = 2000W, T_0 = 308K, C = 10^5 J/K, \eta = 3.3 \tag{23}$$

3.3.1 Curtains

If a portion of solar radiation is reflected by curtains, we'll set the reflectivity at r = 0.5. Using the parameters in the equation (23), the power received in the room will turn into $P_T' = 0.5 \cdot P_T$.

Therefore, the whole temperature falls to

$$\varDelta T = \frac{0.5 \cdot P_T}{\kappa} = 1.25K$$

This correction was to reduce by 1.25K all the temperatures corresponded to t. Similar, the yellow curve moved downward by 1.25 unit as a whole, as shown in Figure 8. The correction can be said that it made some effect. Curtains might be an important means for residents to save air conditioning energy. Especially in the refrigeration for up to more than 10 hours, it may save everal kilowatt hours of electricity.

3.3.2 Human Influences

The heat dissipation power of an adult is about $\mathrm{P_h}$=100W when at rest, totally equivalent to $\mathrm{P_T}$ increasing by 100W. Thus, the whole temperature rose to

$$\Delta\mathrm{T} = \frac{100\mathrm{W}}{\kappa} = 0.5\mathrm{K}$$

This correction was to drop down by 0.5K all the temperatures corresponded to t.

Obviously, the presence of a human imposes an inconspicuous effect on the room temperature, but not so tiny to be ignorable. If a room is used for class there are more than a dozen people here, the warming of a great many students will be considerably apparent.

3.3.3 Atmospheric Refraction

Due to the refractive index of atmosphere, the solar radiation will form a certain deflection when entering the atmosphere. The deflection eventually impacts the $\vec{T}$ in the equation (7). The deflection angle is set as $\delta\alpha$. The atmospheric refraction $\mathrm{n_0}$=1.00027, and $\mathrm{i_0}$ is the incidence angle when the solar radiation entering the atmosphere.

$$\sin \mathrm{i_0} = \mathrm{n_0} \sin(\mathrm{i_0} + \delta\alpha)$$

$$\Leftrightarrow \delta\alpha = \arcsin\left(\frac{\sin \mathrm{i_0}}{\mathrm{n_0}}\right) - \mathrm{i_0}$$

As shown in Figure 13, the maximum $\delta\alpha$ will not exceed 0.025. It is $\delta\alpha \leq 0.004$ when$\mathrm{i_0} \leq 1.5$, thus available to be neglected.

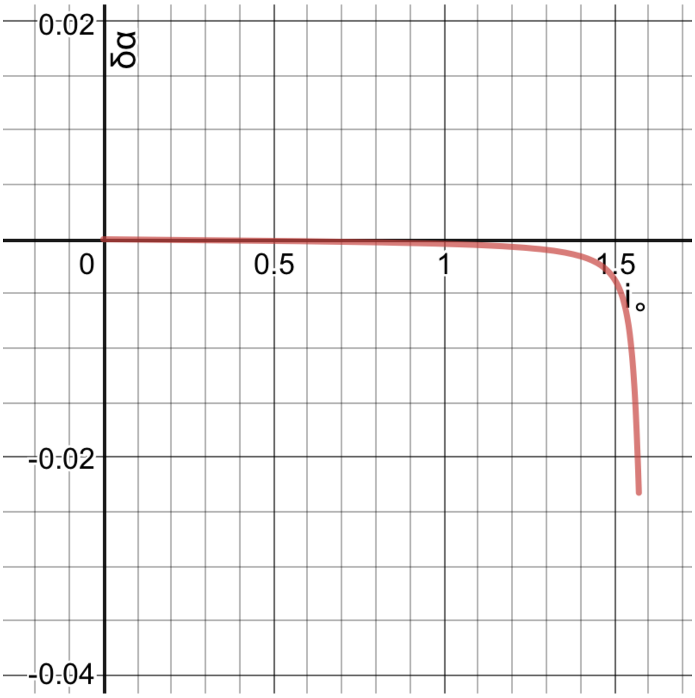


Figure 11: the Deflection Angle of Sun Light Resulted from Atmospheric Refraction Changes with the Angle of the Incident Ray.

3.3.4 Atmospheric Reflection

The atmosphere reflects a portion of the radiation due to its presence. The energy reflectivity of direction p and direction s were given.

$$\mathrm{R_s} = \left(\frac{\cos \mathrm{i}_0 - \mathrm{n}_0 \cos(\mathrm{i}_0 + \delta\alpha)}{\cos \mathrm{i}_0 + \mathrm{n}_0 \cos(\mathrm{i}_0 + \delta\alpha)}\right)^2$$

$$\mathrm{R_p} = \left(\frac{\mathrm{n}_0 \cos \mathrm{i}_1 - \cos(\mathrm{i}_1 + \delta\alpha)}{\mathrm{n}_0 \cos \mathrm{i}_1 + \cos(\mathrm{i}_1 + \delta\alpha)}\right)^2$$

On account of $\delta\alpha < 0$,

$$R_s = \left(\frac{cos\ i_0 - n_0\ cos(i_0 + \delta\alpha)}{cos\ i_0 + n_0\ cos(i_0 + \delta\alpha)}\right)^2 < \left(\frac{cos\ i_0 - n_0\ cos\ i_0}{cos\ i_0 + n_0\ cos\ i_0}\right)^2 < \left(\frac{1 - n_0}{1 + n_0}\right)^2 = 1.822 \times 10^{-8}$$

Similarly,

$$R_p = \left(\frac{n_0\ cos\ i_1 - cos(i_1 + \delta\alpha)}{n_0\ cos\ i_1 + cos(i_1 + \delta\alpha)}\right)^2 < \left(\frac{n_0 - 1}{n_0 + 1}\right)^2 = 1.822 \times 10^{-8}$$

Reflections thus can be neglected completely.

Supposed to be pointed out at last, it was assumed in Chapter 2 that there was an abrupt change in the refractive index the radiation ran from the extraterrestrial space to the Earth's atmosphere. However, both the gas density and the refractive index are gradual, in fact. Nevertheless, the results are greatly possible to be similar.

3.3.5 Atmospheric Absorption

Atmospheric absorption is difficult to calculate in a quantitative way because of being subject to multiple factors. The coefficient of atmospheric absorption is usually lower than 5% in sunny days, between 8% and 11% in cloudy days, and higher than 11% in grey days. To correct the item only needs to multiply the radiation power $\mathrm{P_n}$ in the equation (10) a correction a factor according to the weather forecast.

4. Conclusion

With model establishment and a large number of theoretical calculations, this subject is achieved to present the specific ways how various factors – in particular, solar radiation, air-conditioning refrigeration, and heat conduction-impact the working of an air-conditioner, as well as the importance degree of the influences. A rough relationship was semi-quantitatively determined between various environmental parameters and the refrigerating effect of the air conditioner, by looking up relevant data, establishing appropriate models and rigorous theoretical calculations. Moreover, some interference factors were also put under discussion and correction.

References

[1] Sanaye, Sepehr, and Ali Shirazi. "Thermo-economic optimization of an ice thermal energy storage system for air-conditioning applications." Energy and Buildings 60 (2013): 100-109.

[2] Arora, Ramesh Chandra. Refrigeration and air conditioning. PHI Learning Pvt. Ltd., 2012.

[3] Sumeru, K., H. Nasution, and F. N. Ani. "A review on two-phase ejector as an expansion device in vapor compression refrigeration cycle." Renewable and Sustainable Energy Reviews 16, no. 7 (2012): 4927-4937.

[4] Arora, Ramesh Chandra. Refrigeration and air conditioning. PHI Learning Pvt. Ltd., 2012. [5] Jain, Vaibhav, Gulshan Sachdeva, Surendra Singh Kachhwaha, and Bhavesh Patel. "Thermo-economic and environmental analyses based multi-objective optimization of vapor compression–absorption cascaded refrigeration system using NSGA-II technique." Energy Conversion and Management 113 (2016): 230-242.

[5] Zhao Kaihua. New Conceptual Physics Tutorial Optics [M]. Second Edition. Beijing: Higher Education Press, 2004.

[6] Wang Zhuxi. Thermodynamics [M]. Second Edition. Beijing: Peking University Press, 2005.

[7] Guo Dajun, Chen Yumei, Qiu Zhuoming. Mathematical Analysis [M]. Third Edition. Beijing: Higher Education Press, 2015.