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The CRT monitor versus the LCD monitor

Which is better?

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Introduction

Embark on an epoch that amazing changes are taking place every day, there are more and more revolutions of our electronic devices. As one of the most important parts of the electronic devices, the monitor also has great development. From the CRT monitors to the LCD monitors, we have made our monitors become thinner and thinner, lighter and lighter. Using the LCD monitor, we can make our televisions only 3-centimeter-thick, but 96 centimeters wide and 55 centimeters high, and the LCD televisions also consume much less energy than the CRT televisions do. However, even there are numerous advantages of LCD monitor, some people still use their old CRT televisions in their rooms. We can also see a lot of gamer try to play video games on the CRT computers, and they put their fantastic experience on the YouTube. They are amazed by the instantaneous responds of screens, the bright colors of the pictures, and the high FPS (frame per seconds) of the CRT monitors. Why does this happen? We try our best to make our monitors become better, but the most important function of monitors is degenerated during this revolution. Maybe we can find the answer from the comparison between the LCD and the CRT. Before making this comparison, I think it is important for us to understand how these displays work at first.

What is the CRT monitor?

The CRT is the abbreviation of the cathode ray tube. The CRT monitor is built up by it. Most of the CRT television have only one cathode ray tube. Although we call it tube, but the size of a cathode ray tube is formidable huge, and most space of the devices, which use the CRT monitor, is occupied by it.

[1]

[2]

Image 1 Image 2

The CRT television and its cathode ray tube

How does CRT works?

The main components of a cathode ray tube are the cathode, two anodes, focusing coils, deflecting coils, and the fluorescent screen. From the image[3], we can see that there is an electron beam shoot out from the cathode and fly straightly until it enters the area enclosed by the defecting coils, then the beam changes its direction, and we will get the image on our monitor, when the beam hits pixels of the fluorescent screen. Now, I think there will be some questions. Where does this electron beam from? Why does it change its direction? How does the beam transfer into images when it hit the screen? Below, I will explain these questions in detail.

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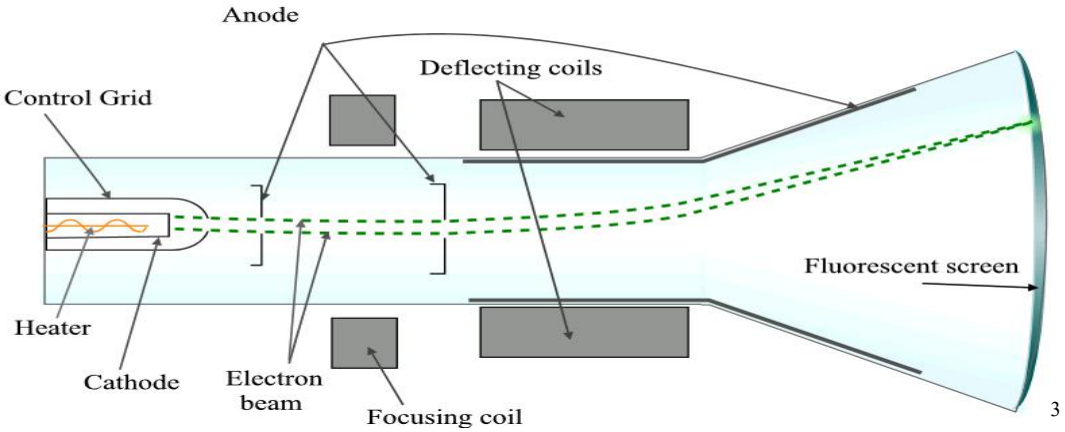
[1] The image 1 was adapted from http://quewebos.blogspot.com/2013/06/mi-dilema-con-la-television.html

[2] The image 2 was adapted from Electronics Take Back Coalition

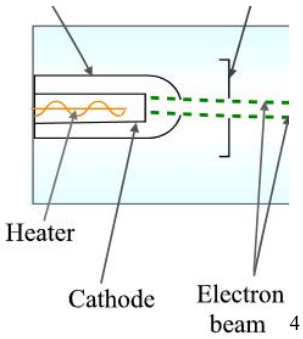


[3]

Inside view of the Cathode ray tube

Where does the electron beam come from?

Before we talk about the electron beam in Cathode, let's think about the electrons in the battery first. When we settle a batter into a circuit, since the voltage of the cathode is lower than the voltage of the anode, there will be electrons flow in the circuit from the cathode to the anode. The terms anode and cathode are used in electronics as synonyms for positive and negative terminals. (http://computer.howstuffworks.com/monitor7.htm) In the CRT, the cathode is the provider of the negative electrons. Since electrons are negative, they will be attracted by the positive anode, when they are emitted by the cathode.



[4]

[3] Image was adapted from https://simple.wikipedia.org/wiki/Cathode_ray_tube
[4] Image was adapted from https://simple.wikipedia.org/wiki/Cathode_ray_tube

However, electrons cannot be pulled out from the cathode by the attractive force of anode alone, since electrons need a plenty of energy to break their bonds with nucleus in the atoms before they escape. The "cathode" is a heated filament. “The heated filament is in a vacuum created inside a glass ‘tube.’ The electrons beam is generated by an electron gun that naturally pour off a heated cathode into the vacuum.”[6]According to the Joule's Law, the current in the filament will generate a huge number of heat. Below, this is the function of the Joule`s Law, which could help us measures the quantity of heat generated by the current in the filament per second.

$$Q=I^2Rt$$

Q is the quantity of the heat, which is generated by the filament, per second.

I is the current in the filament.

R is the resistance of the filament.

t is the time.

When the current heats the filament, the kinetic energy of electrons will increase. The voltage of the heater is very high, which means the current will generate a huge number of heat every second. Thus, after a short time for the heating, the electrons will have enough velocity to escape from the atoms.

Why do we have a pair of anodes in the CRT?

We know that the anode is positive, and they could attract the electrons. Thus, this pair of anodes is an accelerator, which could speed up the velocity of electrons beam, and we will get a clear image on the screen, as high-speed electrons hit the fluorescent screen.

What is the focusing coils?

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[6] Direct quote from http://electronics.howstuffworks.com/tv3.htm

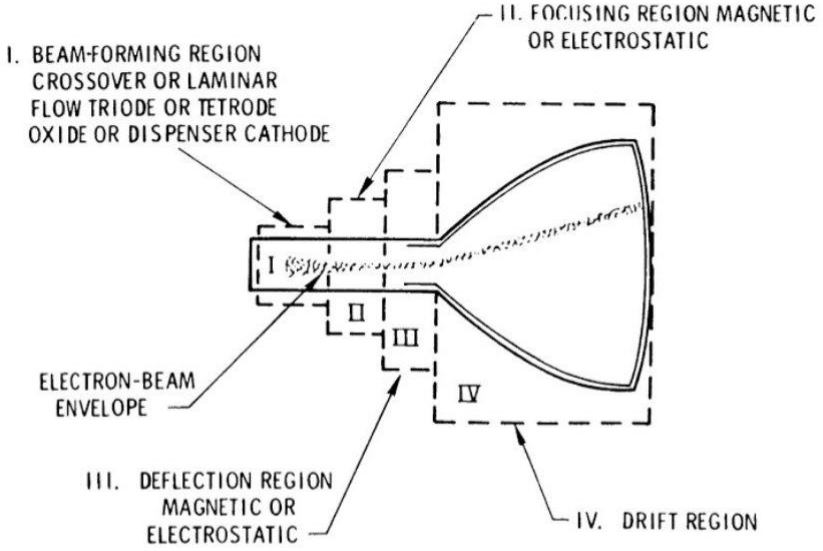
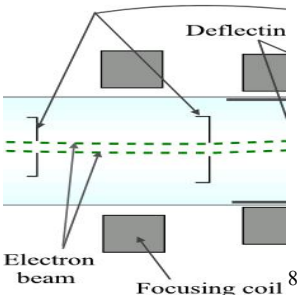


Fig. 6-8. Electron-optic regions of the CRT.

[7]

From the picture above, we can find that electron beam is concentrated into a narrower beam when it enters an area named Focusing region. This region is enclosed by the focusing coils.



[8]

According to the Ampère's circuital law, there will be a magnetic field, when the current flows in the coils. Below, this is the Ampère's circuital law function, which could measure the magnitude of the magnetic field generated by the coils.

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[7] Image was adapted from Flat-panel displays and CRT's page 148.

[8] Image was adapted from https://simple.wikipedia.org/wiki/Cathode_ray_tube

$$\oint BdL = B \bullet 2\pi r = \mu_0 \bullet \sum I$$ [9]

B is the magnitude of the magnetic field.

L is the length of the ampere circuit.

R is the radius of the ampere circuit

I is the magnitude of the current that enclosed by the ampere circuit

As the electrons fly in the magnetic field, they will be deflected to each other and be concentrated into a narrower line by Magnetic Force. The magnitude of this force could be measured by the function below. Using the formula of eccentric force, we find the deflecting radius of the electrons` concentrating motion.

$$F_{magnet}=qvB \qquad F_{eccentric}=(mv^2)/R$$

$$R=(mv)/(qB)$$

F_{magnet} is magnitude of the magnetic force

$F_{eccentric}$ is the magnitude of the electrons` eccentric force

q is the magnitude of the charge of electrons

v is the magnitude of the velocity of electrons

B is the magnitude of the magnetic field

R is the radius of the electrons` concentrating motion

I think you may have a question now. Why do we need to concentrate electron beam? The answer is everyone want to have high quality images on their monitors, so we try

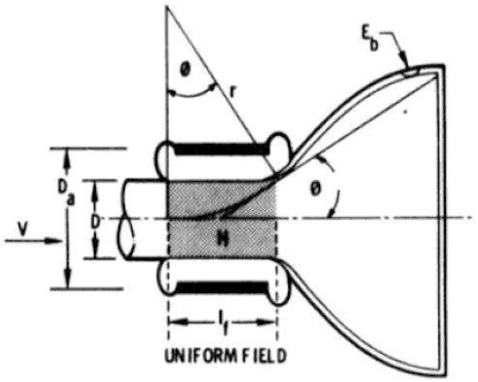
[9] The formula was adapted from http://baike.baidu.com/item/%E5%AE%89%E5%9F%B9%E7%8E%AF%E8%B7%AF%E5%AE%9A%E7%90%86/9102792?fr=aladdin

our best to make pixels smaller. Thus, the electron beam also needs to become narrower, so that it could hit the pixel accurately.

How does the beam change its direction?

You may have been aware of that the electron beam could only hit one pixel per time, but there are thousands of pixels on the screen, so electron beams need to change their directions continually to form an image.

By the same way, which we use to concentrate the beams into a narrow line, we could help electron beams change their directions by the magnetic field generated by the deflecting coils too.



H = uniform magnetic field = ni/D_a
n = Number of Turns of One Pair of Coils
i = Deflection Current
D_a = Inside Diameter of the Yoke Core
v = Velocity of the Electron = $2E_b e/m$
E_b = Beam Acceleration in Kilovolts (Anode Voltage)
e = Unit Charge of an Electron
e/m = Charge to Mass Ratio of Electron or Ion to be Deflected
l = Length of Field H
Ø = Deflection Angle
r = Radius of Curved Electron Path Within Field H
D_n = Inside Diameter of Yoke Coils
L = Yoke Inductance

$$\sin\theta = i\left(\frac{L}{E_b}\right)^{1/2}\left(\ell_f \frac{1}{D_a D_n}\frac{e}{2m}\right)^{1/2} \times \text{constant}$$

*Constant = 1.26×10^{-8} henry with dimensions in centimeters.

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"By adjustment of the current in the coils, the acting force acting on the electron beam can be controlled to deflect the beam to any desire point on the screen. The deflection

[10] Image was adapted from Flat-Panel Displays and CRTs page 153.

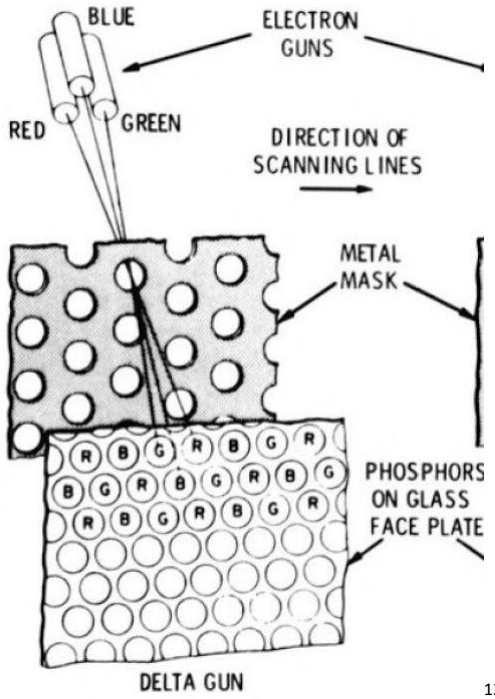
amplitude is directly proportional to the coil current, and inversely proportional to the screen viewing potential."[11]

How does the fluorescent screen make colorful images for us?

Unfortunately, although we have spent a lot of effort to make the beams reach the pixels accurately, but images will not be colorful, unless we use some kinds of special screens.

The CRT screens have millions of blue, green, and red phosphor dots. These dots will glow, when they are struck by an electron beam. The electron beam will sweep from top to bottom of the screen. The illumination of the dots is brief, but the persistence of vision will make it seem that the screen changes instantaneously.

(http://en.tldp.org/HOWTO/XFree86-Video-Timings-HOWTO/video.html)



[12]

[11] Directly quote from the Flat-Panel Displays and CRTs page 153.
[12] Image was adapted from Flat-Panel Displays and CRTs page 143.

Incorporating colors of glowing phosphor dots is also very important for us to make a beautiful image. “To create a precise and crisp picture, it is necessary to make sure that the electron beam for each color strikes only the correct dots intended for use for that color. The normal way that this is done is by using a fine metal mesh called a shadow mask. The shadow mask is designed to the same shape as the surface of the CRT, and the electron beams shine through the mask. By carefully positioning the mask, the beams only strike the correct dots. The idea is similar to one way a sign can be made--a piece of paper is cut out with the shape of the letters and then laid on top of another surface. Then the paint is applied through the holes in the paper; the paper itself prevents the unwanted areas from being colored.”[13]

Advantages of the CRT monitors.

The CRT displays` refresh rate of images is always higher than LCD displays. From the experiments, we know that the low refresh rate may cause the flickering, which is harmful to our eye strain. The refresh rate of most television and computer monitors is more than 60HZ (the images will be redrawn on the displays 60 times per second). Also, the higher refresh rate we have, the smoother video we could see.

The CRT displays are more reliable as well. “From the historical feedback monitors have had fewer problems with ghosting and blurring because they redrew the screen image faster.” [14]

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[13] Direct quote from http://www.pcguide.com/ref/crt/crtMask-c.html
[14] Direct quote from http://computer.howstuffworks.com/monitor9.htm

The CRT displays also have better color representation. “CRT displays have historically represented colors and different gradations of color more accurately.”[15]

According to the experiment, the researchers also found that the CRT monitors performed better in the medical realm. The experiment demonstrated that even the best LCD monitors currently available cannot produce the images of damaged organs like those seen with CRT monitors. (Visual evoked potentials with CRT and LCD monitors page 164)

What is the LCD monitor?

LCD monitor use the liquid crystal as its main component. The liquid crystal has both properties of the conventional liquid and those of the solid crystal.(https://en.wikipedia.org/wiki/Liquid_crystal)Liquid crystals do not emit light directly, instead using a backlight or reflector to produce images in color or monochrome.(https://en.wikipedia.org/wiki/Liquid-crystal_display)Since the liquid crystal has the light-modulating properties, which can be controlled by the electric field, we can change the flux of the backlight`s lightness by changing the arrangement of this liquid crystals in the LCD. More specifically, the liquid crystals have different abilities of transferring lightness in different orientations, so we can change flux of the lightness by changing the orientation of the liquid crystals.

Why does the LCD monitor lose in some areas?

[15] Direct quote from http://computer.howstuffworks.com/monitor9.htm

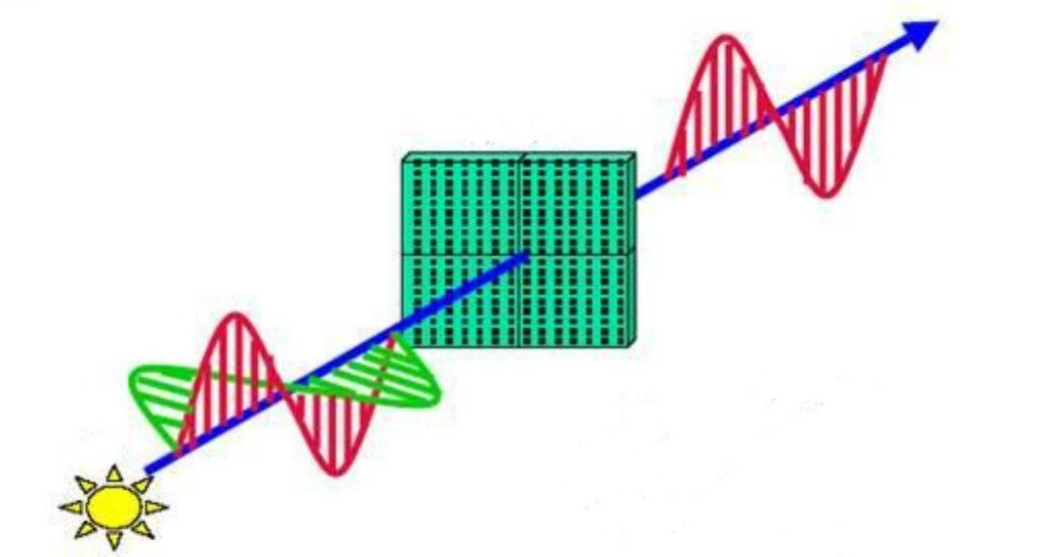
As we have mentioned above, compared with the LCD monitors, the CRT monitors have high refresh rate of images, excellent color representation, and few problems with ghosting and blurring. These are the advantages, which the LCD displays could not match up with the CRT monitors.

If we want to find why the LCD monitors lose in these areas, I think we need a discussion of the LCD monitor`s operation principle at first. A precise comparison between these monitors` operation principles could also explain a lot for us.

How does the LCD monitor work?

The liquid crystals do not like the electron guns in the CRT. The liquid crystals do not emit the light by themselves. However, since they have the property of the solid, they can the transfer light, the light will be transferred along the line of liquid crystals. If we change the arrangement of the liquid crystals, the track of the light will change as well.

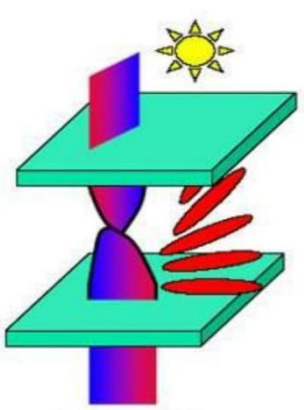
In the LCD display, we need the backlight to provide the light for us. However, the light emitted from the backlight cannot be used by the liquid crystals. Since the normal light waves are mixed up in so many directions, the composition of waves are too complicate for us to control. (http://www.explainthatstuff.com/lcdtv.html)Thus,we need a device to make the light transfer in only one direction and block out the light from the other directions.



[16]

The device we used is a pair of polarizing plates. The polarizing plate is like a filter. When we put a filter in the way, with a grid of lines arranged vertically, we can block out all the light waves except the ones vibrating vertically. (http://www.explainthatstuff.com/lcdtv.html)With a pair of polarizing plates, which lines are perpendicular to each other's, there will be no light come through the polarizing plates, and the pixel normally looks dark. Between the two polarizing filters, there is a line of twisted liquid crystal, which can be switched on or off electronically.

[16] Image was adapted from http://blog.csdn.net/imyfriend/article/details/43820885



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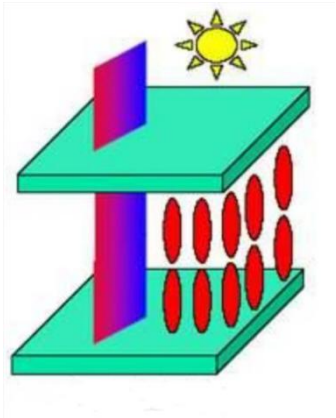
"When it's switched off, it rotates the light passing through it through 90 degrees, effectively allowing light to flow through the two polarizing filters and making the pixel look bright."[18]



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"When it's switched on, it doesn't rotate the light, which is blocked by one of the polarizers, and the pixel looks dark."[20]

The first Comparison:

[17] Image was adapted from http://blog.csdn.net/imyfriend/article/details/43820885
[18] Direct quote from http://blog.csdn.net/imyfriend/article/details/43820885
[19] Image was adapted from http://blog.csdn.net/imyfriend/article/details/43820885
[20] Direct quote from http://blog.csdn.net/imyfriend/article/details/43820885

The illuminate strategy of LCD is blocking. We can find that is a very negative method for illuminating, since the max brightness of the display will be the brightness of the backlight, and we will waste most of the light during the illumination.

In contrast, the CRT use the high-speed electron beams to glowing the phosphor dots on the screen. During this process, most energy of the electron beams are transferred into the luminous energy of the phosphor dots.

Thus, there is no doubt that the images on the CRT screen will have brighter color. The high energy electron beams make the CRT monitor have a larger range of brightness, which ensure the monitor could present different gradations of color more accurately.

The second Comparison

In the CRT monitors, each time, the energy of the electron beams will have a tiny difference, when they hit the phosphor screen. Thus, even the pixel has the same color, the brightness of the pixel may have some change, when the pictures are redrawn on the screen. This change will cause visible flickering on the screen, when the monitors have low refresh rate, which is totally harmful to the humans` mind. To eliminate this flickering on the screen, we must keep the refresh rate up to 60 times per second. (http://blog.csdn.net/wu_chung_tang/article/details/2034520)

However, when the LCD monitors redraw the images, the brightness of pixels does not change, since the brightness of the backlight is very stable.

(http://blog.csdn.net/wu_chung_tang/article/details/2034520)Thus,we do not need to worry about the flickering. To save the energy and protect the circuit in the monitors, the LCD monitor may have a refresh rate which is lower than 60HZ.

The third Comparison

The respond time of the screen is the time which electron beams need to hit every phosphor dots of the screen. This time is inversely proportional to the speed of the electron. As a fact, the speed of the electron is only the one percent of the speed of the light, however it is fast enough to make CRT monitors have instantaneous response time.

The response time of the LCD monitors is the time which liquid crystals need to change their orientations. However, it is not easy to change the orientations of the liquid crystals, which means it will take a long time to change the color of the pixel.

From the historical data[21],the response time of the CRT monitor is less than 1μs.However, the response time of the LCD monitor is more than 1 ms (1 ms=100μs), older units could be as slow as 35 ms.

From comparison above, we can conclude the CRT monitor has overwhelming advantage in its instantaneous response time of screen.

Why we replace the CRT with the LCD?

[21] The data are from https://en.wikipedia.org/wiki/Comparison_of_CRT,_LCD,_plasma,_and_OLED#cite_note-9.

The CRT monitors have overwhelming advantages in processing images, but we still replace them with LCD monitors. It is not only because of LCD monitor`s small size and light weight, but also because of we have change the ideas about what we want from the science.

In the past three hundred years, two revolutions have taken place in the industry. In both revolutions, we wanted to overrule the nature and took advantage of every natural resource we could get. The giant machines were working in coal mine day and night, until the mountains above were crushed into the ground during the exploration. The smoke of power plants blew the sky of countryside, just because the people, who lived in the city, need the a plenty of electricity to power their CRT televisions. The toxic screens of monochrome CRT were sent to the landfill without enough purification, when people just want to replace them with the color CRT televisions. These are the ridiculous things that should be stopped. Thus, in the third revolution of the technology, people have begun to change their ways, in which they treat the environment, from the ruling to the coexisting, and we know that we have enough reason to discard our CRT televisions.

Reasons

The CRT monitors will emit a small amount of the X-ray radiation when it bombards phosphors. (https://en.wikipedia.org/wiki/Cathode_ray_tube#cite_note-47)Although the amount of the radiation escaping from the monitors is considered not to be harmful, it is still unhealthy for the people to watching the CRT televisions for a long time.

The old CRT monitors also contain the toxic substance in the phosphors, so the recycling of these old monitors will be very difficult. According to the Neil Peters-Michaud, “Workers in electronics demanufacturing and CRT glass recycling operations may be exposed to heightened levels (near or above OSHA required limits) of lead, cadmium, chromium, barium and other heavy metals, as well as other workplace hazards. ”[22]

Also, the heater of CRT will consume number of energy, when it is working, however most of the energy will not be transferred into the energy of the electron beams, but they will become the waste heat of the heater and emanate to the environment. No doubt these waste heat will intensify the greenhouse effect as well.

Conclusion

We must admit that the most of CRT monitors have the higher refresh rate, better color representation, and instantaneous response time. However, they are not good reason for us to judge that the CRT is better than the LCD, since the criteria that we use to assess the best monitors has changed. We want to coexist with our environment and have more amazing discoveries of the nature and the universe on the earth. Thus, the LCD monitors, which consume less energy and cause less problems to our environment, will continually replace the CRT monitors in our everyday life. As the development LED technology, we are trying to replace the backlight of the LCD monitors with the light emitting diode, and we may make our monitors combine the advantages of the CRT and the LCD in few years.

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[22] Direct quote from Occupational Risks Associated with Electronics Demanufacturing and CRT Glass Processing Operations and the Impact of Mitigation Activities on Employee Safety and Health

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