Calculating Light Requirements

You must consider four major factors that affect exposure when you are taking photographs. These factors are as follows: Film speed (ASA/ISO) Reflected properties of the subject, Lighting conditions, and shutter speed/aperture combinations.

When shooting with film, it is better to be a little over-exposed than under-exposed. What happens when you are under-exposed, the shadow areas can turn the film completely clear, thus saturation and losing all detail. On the other hand, over-exposing the film will give you more detail. However, as we have explained, it is always better to make sure your exposure is exactly proper.

Having explored some of the rudimentary points of light behavior and specifications, let us set up a hypothetical lighting situation and determine what is needed. We will discuss different aspects in the following sections. We will get into multiple light sources, diffusions, and other techniques in other articles. In the meantime, in order to keep things simple, we will set up our scene in the following way. We are going to start with a single incandescent lamp in a reflector. Our subject will be human – which is prone to a certain amount of movement. Our objective is a sharp and high quality photograph. Let us set up some other parameters for our scene. We are going to use ASA/ISO 100 speed film, a lens aperture of f11 in order to get good depth of field and a shutter speed of 1/60 of a second in order to have lens sync.

In situations where there is little or no light available, a portable electronic flash unit is an invaluable piece of photographic equipment. With fast films and long exposures, you may be able to shoot existing light pictures, providing your subject remains motionless long enough. Although you can certainly get better lighting control with elaborate photographic lights, the simplicity and portability of electronic flash is unbeatable. Electronic flash provides an excellent source of artificial light for exposing black-and-white and color daylight-balanced film. Light from an electronic flash unit (strobe) is characterized by softness, short duration, and color balance, approximating that of daylight. By measuring the amount of light that actually reaches an object or scene, you can obtain a numerical value that can be converted directly into a flash guide number. The numerical value is the light output rating of an electronic flash unit measured in beam candlepower-seconds (BCPS) or more correctly, effective candlepower-seconds (ECPS). Every electronic flash unit is assigned a guide number as a measure of its light output or power. The higher the guide number, the greater the light output.

Continuous Light Source

In order to get even lighting, we are going to place our one light six feet from our subject – a human. By referring to appropriate charts or an exposure meter, we find that thirty-two Foot-candle seconds (FCS) are needed to make our exposure of f11 with film speed of 100 ASA/ISO. This is assuming one second. However, we need to shoot at one-sixtieth of that in order to freeze our subject and not get any motion. In order to expose our scene at 1/60 of a second, we need to multiply our thirty-two FCS by sixty. This brings us to 2000 Foot-candles of light intensity. Since our light is six feet from the subject, we will need six-squared (thirty-six) 2000 BCP or 72,000 BCP from our light source. We can typically expect a reflector gain (concentration factor) of around six. So now, we have the required 72,000 BCP only needing around a 12,000 CP bulb. Here is a dumb question – I have never seen light bulbs rated in CP, so how do I find one with these specifications? I will tell you the formula. The average incandescent light bulb produces about 1.5 CP per watt. Wow! That gives us a light bulb of 8000 watts. I do not know about you, but I have never met one, even in The Home Depot. Even if we were to find one, we would need a huge air conditioner just to be able to walk into the room, forget about the huge electric bill – especially at today's electric charges.

If we are going to meet our objective using these settings with an incandescent light bulb, we will need to use several high-powered bulbs that are usually found in Hollywood in their studios. Since most of us cannot afford to purchase and use them, we now have the unfortunate conclusion to degrade our settings. This would include raising the film speed, lower apertures, and slower shuttering speeds.

We do not want to do this, so the photographer has another ace up over the video crews. We are only concerned with a moment in time, not about several seconds. Most of the time, we are dealing with 1/60 of a second.

Let us go back to our hypothetical situation above and turn on the 8000-watt lamp for only 1/60 of a second that we actually need in on for to make our exposure. We would now need an *amount* of power equal to 8000/60 or 133-watt seconds in order to make our exposure. Now that we are thinking of amounts instead of intensity, we can now redo our mathematics and see that 133-watt seconds of electrical power fed into the incandescent bulb will produce the thirty-two Foot-candle Seconds of required scene illumination. Now, we could achieve the 133-watt second amount in a variety of ways. Of course, we could turn on our 133 watt second light for one second, but we would have the problem of our subject moving and blur would show up on the film. That is not what we want to accomplish. Therefore, we look for another direction. We could use a 133,000-watt bulb and turn in on for 1/1000 of a second. In any way we combine wattage vs. time to come up with 133-Watt seconds, we find that a relatively small amount of actual power is needed – 133 watts per exposure per second. Now we do not need that high-powered air conditioner unit for this. There is only one small problem with this. How do you turn on a light bulb of 133 watts for 1/1000 of a second? It takes more than that just to warm up. It is not practical.

Electronic Flash Systems

Enter the Electronic flash system to assist us in solving this problem.

Electronic flash tubes are filled with Xenon gas. A small charge of electricity is trickled into a storage capacitor or capacitors inside the strobe unit. The charges build up to produce a huge chunk (amount) of energy. The capacitor terminals are connected directly across the electrodes in the flashtube. Nothing happens until something triggers a pulse to a third terminal in the flashtube. Then what happens is exactly what happens in a bolt of lightning. The gas ionizes, forming nearly a short circuit across the capacitor. An avalanche of current results and the energy stored in the capacitor is dissipated in a brief flash of extreme intensity of light. The duration of the discharge of light can be anywhere from 1/100 to 1/100,000 of a second. After each discharge (flash), the capacitor is recharged ready for you to take another photograph.

We can now see that there is a distinct advantage to using a xenon flash system over an incandescent lighting. However, there are other advantages also.

Its efficiency in converting electrical energy to light can be almost as much as four times Candle Power Seconds per Watt Second. This means a fifty-watt-second flash can produce as much light as would be required for 133 WS in an incandescent bulb.

- The color spectrum produced is very close to the natural sunlight spectrum.
- The flash tube is more consistent over its life as compared with an incandescent light.
- The flash tube varies very little if at all if there is a change in voltage on the power line.
- The life expectancy on a flash tube can be anywhere from 2500 to 100,000 flashes.
- Exposure times can be very brief.

On the other hand, there are a few disadvantages, but in my opinion, they are minute compared to the advantages mentioned above.

- They are comparatively expensive in relationship to incandescent bulbs.
- There is a delay in taking photographs while waiting (seconds) for the system to recycle.
- It can be difficult to predict the light pattern without seeing the results from a light bulb (this can be corrected – we will talk about it later).
- As the tube starts to die, there is a slight color shift.

Automatic Electronic Flash Units

Most electronic flash units can be operated in an automatic exposure mode. An automatic flash unit eliminates the need to determine the correct f/stop for each flash-to-subject distance, providing the subject is within the flash distance range of the unit. On the front of an automatic flash unit, a sensor reads the light reflected from the subject that is produced by the flash. When this sensor is satisfied with the amount of light received, it automatically shuts off the flash. The closer the subject is to the flash unit, the quicker the sensor shuts off the light. Some automatic electronic flash units allow you to select two or more apertures to control depth of field. To determine an f/stop in the automatic mode, you can use the calculator dial, located on the unit that is being used. By matching the indicator to an ASA/IS0 film speed number on the dial, you can use the f/stop within a minimum and maximum distance. Once an f/stop is selected and set, it becomes a constant factor regardless of the flash-to-subject distance, providing it is within the flash distance range of the unit. This feature allows the photographer to move closer to or farther away from a subject without having to calculate an f/stop for each change of flash-to-subject distance.

For example, if you are shooting with your camera set to f/8 you can set your off camera flash unit to f/11 in the automatic mode. This will give you some nice definition and the unit will always deliver an f/11. Not all units are this sophisticated, however some are.

Battery Powered Portable Flash Units

This section is going to talk a bit about the flash units we have all used. These flash units sit on top of our cameras. They are quite effective and almost everyone uses them, especially photographers. The typical units are more than enough power to cover what we talked about previously.

The modern portable flash units are computerized and can deliver a specific amount of light to your scene and withhold the additional power for the next flash. This is called thyristor circuitry. It helps save on battery power as it only uses the right amount of power and saves the rest for the next flashes. Flash duration on these units are typically 1/1000 of a second when operated at full power. If you are using it at less than full power, the duration is going to be shorter.

Battery powered flash units are usually designed to mount onto the camera and will concentrate the flash output to just cover the area seen by a camera with a normal (50mm) lens. Outside of this area, there is a rapid fall off of the light to the point where it is no longer useable. However, there are ways to compensate for this fall off. For example, you could use a wide-angle attachment or a diffuser.

These units recycle quickly (anywhere from 8-20 seconds). However, their recycle times will vary as to how much power it is using in each flash cycle, and how charged the batteries are.

One of the biggest problems they have is when you take them off the camera and use them as one would use them in a studio setting. You can easily trigger them in one of several ways. You can use a sync cord that connects the camera and flash. Another option is to get a light sensing diode that you attach to the flash unit. If you have a flash unit on the camera, the other flash will “see” the camera flash and trigger itself. The third way is to use a radio slave.

Another problem you will encounter with off-camera flash units is the inability to preview exactly what the light pattern will be. When the unit is on the camera, the illumination will invariably fill the frame, and the only thing you have to worry about is how far the light will travel from front to back of the scene.

The problem with this form of lighting is that it is very boring and does not lead to creative lighting and photographs.

As soon as you take the flash unit off the camera in order to obtain more pleasing lighting effects, you only have your imagination and experience to tell you what the illumination pattern is going to look like on the final photograph. When you see the results, you realize that the pattern of light that is delivered by most portable flash units is quite unflattering. The rapid fall-off outside the primary light angle may now very well fall within the scene, causing bad lighting and shadows in bad places. Here again, we need to have a preview capability. In addition, there is the problem that this flash unit delivers a type of light that is very harsh as it is a very small light source. As soon as you take the flash off-camera, shadows begin to form on the subject. While it is these shadows, which can give the subject more pleasing life-like lighting, they can also give a bad look to the photograph if the shadows are in bad places. This is better than the on-camera lighting, which gives a head-on, hard, “mug shot” type of look.

An experienced photographer can overcome many of these problems by the careful use of diffusion techniques such as bounce lighting and umbrellas. Such techniques, however, will reduce the available light on the scene and therefore a higher flash power is needed. This still does not take care of the lack of preview problem. The other problems are also that they require long recycle rates and they need to have their batteries changed regularly.

AC Powered Studio Flash Systems

When discussing in the previous section we mentioned that there were several problems. Engineers have come up with a variety of systems that can help us eliminate some of these problems and at the same time, they address some other issues.

The AC powered studio flash systems are designed primarily for the studio setting, however for the most part they are portable enough to take on location.

One of the distinct advantages of these systems is the fact that they usually come with some sort of continuous light source for previewing the light pattern. This is called a modeling light, since it models the actual pattern of the flash. Most often large reflectors are used and they are often less directional and do not cut-off the light pattern as sharply when outside the angle of primary illumination. There is a draw back here is with these large reflectors. This drawback is that when using the reflector (read umbrella) they require much more power to produce the same exposure as when not using a reflector.

The advantage of using a reflector, diffuser, umbrella or soft-box is that they make the light more flattering.

When using these diffusers to make the light softer the BCPS rating will be lower than for a similar unit without the reflector. This, however, does not indicate less efficiency or less light output. It simply indicates the light output is made to cover a wider area. Please understand that the more diffusion or the larger the umbrella or soft-box will cause a greater loss of BCPS. Therefore, a high BCPS may be deceiving, as diffusion techniques may reveal a much lower actual flash power.

Because using diffusion will reduce the amount of light produced, most studio flash systems offer a higher power to compensate. When I say higher, I am referring to as compared to portable flash units. Very often studio flashes are used in multiple. This means a photographer will use two, three, four, or more units. Most of the wedding photographers will use between two and four lights, sometimes more.

Typical recycle rates for these units will range from instantaneous to six seconds depending on the power of the unit and how much of capacitor is drained. These units also have variable power settings so that you can adjust how much light will illuminate your scene.

Modeling Lamp Systems

I like modeling lights in my studio flash units. They produce a light pattern of the lighting effect the flash unit will cause when making an exposure. In order to accomplish this there must be an exacting correlation between flash and model light in a number of parameters. The modeling lamp must be mounted in the same reflector as the flashtube, and must be positioned in such a way that the projected pattern from both sources as nearly identical. The degree of the pattern correlation varies from design to design, and is a difficult parameter to control since two separate light sources should be placed at the exact focal point in the reflector. Most units will project a somewhat broader beam during modeling with respect to the flash pattern. With careful design, the two patterns may be made close enough to allow you to be confident during preview. If gross errors exist in pattern correlation, which they do in poorly made systems; the result can be hot spots or dark areas on the photograph, which were not seen under the modeling light.

When multiple lights are used, it is even more critical to have a constant ratio of modeling light intensity and flash power on all lights in your system. In addition, it is very important to have the modeling lamps adjustable and corresponding to the flash power output. Only under these circumstances can the light ratios be judged effectively for your scene. This is true whether you are shooting people or commercial work.

I know some beginner users to this system are concerned that the modeling light will give the photograph a warm look due to the yellow cast of the modeling light. Let me assure you that this is not a concern. The reason is that the flash output is over one thousand times that of the modeling light, so it is not going to be seen by the film. Its color temperature will have no effect on the resulting photograph.

Power Pack VS Self Contained Units

There are two types of studio strobe units that incorporate all of the above features. As with everything else, there are advantages and disadvantages to both of these systems.

One system is the power pack type of unit. This is where there is a central unit, which supplies power to one or more flash heads. In this system, the charging circuitry and capacitors are contained in this separate, central power supply. The flash heads are connected via heavy cables and have in them only the flash tubes, modeling lamp and the triggering circuitry. The advantage of this system is that the heads are less expensive, lighter and more compact than the next system we are going to talk about. The disadvantages are:

- If the power pack fails, the whole system is down
- Each flash head is limited to what the power pack can supply to it if multiple heads are attached
- There are wires over which someone can trip.
- The location of the heads are limited to the length of the wires
- There is a slight loss of power in the cable.

The other system, which is the one that seems to be more popular (at least as I have seen), is the self-contained unit. Modern units are quite impressive. Some of the higher power units have built-in cooling units. These units are compact and lightweight and therefore are easier to use for the photographer who does much of his work on-location, for instance a wedding photographer. The self-contained system have their modeling light, flash tube and power pack all built to the highest standards so that everything is optimally compatible with each other. This is something that might not always be the case with the power-pack system. Since each individual unit has only one wire, and that wire is the ac wire, you are not constrained as to where you can place the units. You are not tied down to the power pack, since each unit has a self-contained power pack. The only current that runs through the ac wire is your basic electricity; you can use your household extension cords when necessary. The one challenge is that each unit needs to be synchronized to the camera, as opposed to the power-pack system, you only need to synchronize the one power pack to the camera. There are several ways to do this. This is actually quite easy. All you need to do is find a way to synchronize one unit to the camera, and the other lights probably have a built-in slave to fire the other units. As we talked above, there are several ways to do this. You can use a light sensing slave or a radio slave.

One of the distinct advantages of this system is that if one unit fails, it does not take down your entire system, as each unit is self-contained.

More advantages and disadvantages in the next section, under *Watt Second Rating*.

Determining Effective Flash-Power and Exposure

There are three methods manufacturers of strobe and flash equipment use to tell customers (photographers) how much power they have.

1. Watt second ratings
2. BCPS
3. Guide number

Unfortunately, none of these is very accurate in describing actual flash power of the unit. In order to make some sense of these ratings, we are going to take them one at a time.

Watt Second Rating

Watt Second defines the amount of electrical power supplied to the flashtube(s) not the amount of light the tubes emit to the scene. There are several design factors, which affect how efficiently the flashtube converts electrical energy into useable light. These same factors also affect the flash duration. The same parameters, which tend to decrease system efficiency, also work to shorten flash duration. This is so potentially to the point of inviting reciprocity induced color errors.

The use of high values of flashtube current with lower flash voltages results in the longer flash durations – for example 1/1000 of a second, and the higher conversion efficiencies approaching 4CPS per WS.

Inversely, systems using lower currents but higher voltages tend to be less efficient and produce shorter flash durations.

A second major consideration is the "loading" of the flashtube. "Loading" simply describes how much power is fed to a flashtube, relative to the amount of power it was designed to dissipate. From this we can say that a 200 WS flashtube is operated at 200 WS, and then it is optimally loaded. In this way the strobe unit produces a long flash duration and high efficiency. For example, it is fed only 50 WS then it is considered "lightly loaded" and will produce a very short flash duration (maybe 1/5000 of a second) and fewer CPS per WS – less efficiency.

On the other hand, if it were operated at 400 WS then it would be overloaded and would die an early death.

There is actually a third potential cause for a lowered efficiency in output. This would be a loss of power in the connecting wires between power supply and flash tube. It is worse with a central power supply system. Since losses due to cable are a function of cable length and the flash current (not voltage), most central power supply system's employ high voltage/low current circuitry in order to allow reasonably long lengths of cable to connect from the power supply to the flash heads. These cables have to be of manageable diameter, in order to maintain minimum power loss in the cables.

There is another feature with the central power supply system that can be either an advantage or disadvantage (depending on how you look at it). This feature is that with a central power supply system the flash tubes are generally "lightly loaded". This is done in order to have flexibility so that there will not be a system overload with the use of different flash heads.

Let us take a hypothetical case in order to make this a little clearer. We are going to take a four hundred WS power supply with four 2400 WS flash heads. We will have the power supply working at fifty percent power. Each flash head is designed for 2400 WS is now operating at fifty WS. This is very inefficient and will produce extremely short flash durations. The duration will probably be less than 1/8000 of a second.

Now that we understand the inner workings of the central power pack system, let us move on to the self-contained units and see how they operate. The same factors we are going to discuss apply to both self-contained units and portable flash units (the type that fits on top of your camera). These units use low voltage/high current power supplies, and they employ flashtubes somewhere near the point of optimum loading. There are no connecting cables as in the central power supply units. The AC power cable does not carry any actual flash current; it only thing it does carry is a much lower current that is used to charge the capacitor. It does not play a roll in power efficiency or duration. With all this in mind, we can now see that these units will produce the highest possible efficiency as well as generally optimum flash durations. Many of these units can be reduced down to very low power. In such a situation, efficiencies and flash durations will be reduced.

Now we can see that WS specification serves only as a general guide to real useable power. It can be expected that the average self-contained system will produce light energy at the rate of near four CPS per WS. On the other hand, a Central powered system can vary substantially with configuration. You can expect typical variations in the range from 2.5 to 3.5 CPS per WS.

Even with the draw backs we saw above, we will see shortly that WS rating is by far the best determining factor of useable flash power over BCPS rating or Guide number.

BCPS Rating

Beam Candle Power Second Rating. This rating defines the amount of light that is actually *projected* by the system. The problem is that it does not tell us accurately how much light is *produced* by the light unit. As we discussed earlier @@@@@@ BCPS rating includes the magnifying effect of the reflector. The reflector does not actually increase the amount of light; it simply redistributes or focuses the light into a smaller field. Conceivably, someone could design a highly focused reflector which could be used on a very low power flash tube and come up with a very high BCPS rating by concentrating all the available light into a very small sized spot on the wall. The spot on the wall would be very intense, but would serve very little use for the average photographer. If we would take this very high BCPS and point it into an umbrella or other such softening device, the light would spread out and cover a larger field. We would then see how low the power really is.

On the other hand, this rating system would be ideal for use with the on camera style flash units. The reason is that they are not designed to be used with a reflector as apposed to the studio strobe units. It is the norm for studio strobe units to be used with some sort of light modifier or several modifiers. Portable flash units generally project a narrower pattern and have a higher gain reflector than do studio strobe units. Consequently, they will usually have more loss when used with diffusion or bounce. You cannot compare BCPS or GN when bounce or diffusion is used.

Guide Numbers

This is an interesting number as it is just a different way of stating BCPS. The guide number tells you what aperture setting you will need on the camera for a given light to subject distance at a given film speed. For example, if you are using ASA/ISO 100 film and the flash you were using has a guide number of 110, and you were ten feet from the subject, you would use an aperture of f11. Looking at the appropriate charts you will find that with an ASA/ISO of 100 and guide number of 110, it is the same as a rating of 2800 BCPS. Just as we said before, the guide number is only good if you are using the flash direct without any modifier.

Please understand that the guide numbers on most flash units are rated for 100 ASA/ISO at ten feet. It is very common for the manufacturers of strobe units to over rate their equipment a little. It is recommended that you do your own test with a flash meter. Here is how you go about doing this. Set your flash meter to 100 ASA/ISO. Measure out ten feet. Take a reading of your flash as it is fired from that distance. If perchance you get a reading of f8 ½, your guide number is eighty-five.

Electronic Flash Guide Numbers

Electronic Flash Exposure

Use the guide numbers in the following table as a standard for its particular film. Select the output closest to the number given by your flash manufacturer. Then find the guide number for feet or meters. To determine the lens opening, divide the guide number by the flash-to-subject distance. If your films are overexposed, use a higher guide number; if they are underexposed use a lower number.

For ASA/ISO of 100

Output (BCPS)	350	500	700	1000	1400	2000	2800	4000	5600	8000
Guide No. (For Distances in Feet)	40	50	60	70	85	100	120	140	170	200
Guide No. (For Distances in Meters)	12	15	18	21	26	30	36	42	50	60

For ASA/ISO of 160

Output (BCPS)	350	500	700	1000	1400	2000	2800	4000	5600	8000
Guide No. (For Distances in Feet)	55	65	75	90	110	130	150	180	210	250
Guide No. (For Distances in Meters)	17	20	22	27	33	40	46	55	65	75

For ASA/ISO of 400

Output (BCPS)	350	500	700	1000	1400	2000	2800	4000	5600	8000
Guide No. (For Distances in Feet)	85	100	120	140	170	200	240	280	340	400
Guide No. (For Distances in Meters)	26	30	36	42	50	60	70	85	105	120