REFLECTOR DESIGN and EXPOSURE CONTROL for CONTACT LIGHT SOURCES.

Ernest Ohlig *

Abstract: Much of the quality of a finished printing job depends on the transfer of images from the original art or type to the finished printing plate. Pre-press depends on photographic processes, all using light sources. Through modernization and automation, to improve efficiency and economy, much progress has been made in the development of light sources to accommodate the exacting requirements of the Graphic Arts. This Paper will address design parameters and features of high power light sources for contact exposures and methods to determine the quality of illumination on a contact frame.

It will address the basic and sometimes complex considerations that go into the choice of lights and the results that can be expected; it will deflate some of the misconceptions about lights and exposures; it will give a technical insight into the design and engineering department's difficulties in finding the compromise that will be economically feasible, yet meet the requirements of the Graphic Arts Trade; it will address specifically the matter of safety and comfort for the operator and management of trade departments; it will cover in some detail the common light sources used in contacting.

* President, OLEC Corporation, Costa Mesa CA USA

INDEX

A. COMMENTS

For several years numerous Craftsmen, Designers, Engineers and Technicians in the Graphic Arts have urged me to document technical information. A wealth of data has been collected through the OLEC Corporation. I add my personal experience of thirty years in the design, manufacture and service of lighting equipment, used in the exposure of photosensitive materials. To my surprise I found that very little has been published on the subject of contact exposures and lighting. Our research was unable to locate papers on this subject.

There seems to be no question regarding the importance of contact exposures in Pre-Press. All too often it is the weakest link in the chain of processes that are eventually fused into a quality printed product. Personal opinions and "rules of thumb" abound, but so many are erroneous or outdated. This paper will examine some. Due to the lack of supporting material and the abundance of subject matter, I decided to give an overview of lighting and its effect on contact exposures in this paper.

To avoid unwarranted controversy, no actual exposure tests are published here. Our experience shows different results with some of the materials available. It will be more appropriate for the manufacturers of sensitized materials to publish the results of actual exposure tests conducted under their supervision. I can pledge my own and our company's cooperation in the interest of education and progress in the Graphic Arts.

I extend a challenge for further research and more detailed work on the subject of lighting, contact exposures and different phases of the pre-press exposure.

B. Definitions.

This Paper addresses the subject of Contact Exposures for Halftone and Line subjects only. It does not refer to Continuous Tone subjects, yet most contentions do apply.

"Standard Frame" referred to is of the following dimension: 30" by 40", 0.75 x 1 m.

"Standard Ceiling" referred to is considered a height of: 8', 2.44 meter.

References to a "Point Source" or "True Point Source" are in some cases considered a point without dimension. The word Point Source is abused in our trade.

For reasons of standardization we use the following terms:
Light or Light Unit = Light Fixture; Lamp = Bulb, Tube, Light Emitter.

Height of Light is considered the part of the reflector closest to the exposure surface. The total reflector may become the light emitting area and the position of the lamp within the system becomes irrelevant.

Measurements are in foot, ', inch, ", meter, m, mm,
mil = one thousandth inch, micron = one millionth meter.

Spectral radiation is listed in nm, nanometer. Temperature is listed in degrees Celsius.

C. Change through new Sensitized Materials

Numerous new contacting materials have made it possible to bring operators out of the darkroom into a bright and healthy environment. It has enabled companies to make better use of space and human resources. We refer to these products as "Out of the Darkroom" materials. Used with relatively high ambient illumination, high power lights have replaced many of the 100 Watt Point Lights, conventionally used for contact exposures. Two basic requirements have developed: one for Quartz-Filament lights in the range of 3,200 to 3,400 degree Kelvin, for the exposure of materials sensitive to far blue, violet and the very near UV, the other for Mercury Halide Discharge Lamps, peaking in the violet area of the spectrum around 410 nm or the near-UV, part of the UV "A," around 365 to 380 nm, with much greater intensity. Other materials are sensitive to even shorter wave UV in the 340 to 365 nm band.

D. General Reflector Design Considerations

Reflectors are optical systems and careful design is the basis for high efficacy, utilization of the available radiant emission, light intensity as well as evenness without excessive falloff or varying intensity patterns (homogeneousness) over a predetermined area. A compromise must be struck between "quality" and intensity.

To establish design parameters, consideration is given to the dimension of available space, supply power limitations, intensity requirement, safety and general work surrounding. Larger reflectors can increase efficiency; yet large light emitting areas lead to "soft light," increased undercutting. Greater distance produces a higher degree of collimation. The desired photographic result, available space, user safety and comfort demand specific treatment of design.

D. 1. Safety and the Law.

In the design, just as in buying, selling or recommending a light, the first test is: does it meet the exposure requirements? Beyond the rather basic demand of application, economy and serviceability, etc., designs should conform to laws that pertain to safety. This is easier said than done. Requirements differ from country to country. They are not well defined at times, due to the specialized use of such fixtures in the Graphic Arts. The necessary examinations by testing laboratories are often cumbersome, time consuming and expensive.

In the USA, light fixtures used in commercial and industrial environments must be designed to meet OSHA requirements to avoid the potential harm that could arise out of their use. Safety for operators and others in the same working area is most important. Injuries, property losses and costly litigation may be the result of poor design. A wise manager or owner will also insist that installations are made in accordance with building codes and will meet all local bylaws.

One of the basic conditions of building codes requires special approval for light fixtures mounted on or above a ceiling or into a ceiling cavity. It stands to reason that a fire started in such a confined area can spread without being noticed for some time. It may not set off the sprinklers or alarm devices mounted at lower elevation. Chances of a high power light of safe construction causing a fire are very slight but it is still unwise to take such a chance.

D. 2. Basic Height Restriction.

Most common ceiling height in rooms, formerly used as darkrooms, in art departments and many in-plant or smaller shops, may be as low as 8', 2.44 meter; in this paper it is referred to as "Standard Ceiling." A designer may use that height as a maximum, still covering an exposure area of the common 30"x40" frame, 0.75x 1 meter; in this paper it is called the "Standard Frame." Some plants have high ceilings, and some applications demand further distance between light and sensitized material. Designing lights for a lower ceiling height can preclude the temptation by the user to mount the light contrary to good safety practice and the law.

A "rule of thumb," still quoted by many, calls for the minimum distance from light to "Standard Frame" as 5', 1.5 m, others insist on the diagonal as the closest. Yet on "glass down" frames and "turn tops" the distance is often as short as 2', 0.6 m. Such lights may be quite adequate to perform many exacting functions.

Assuming one uses the "diagonal rule," a height of 50", 1.27 m on a "Standard Frame," the necessary ceiling elevation can be established as follows: adding the usual height of the frame top, 34", 0.86 m, to the distance from frame to light, leaves a space of 12" or 31 cm under the "Standard Ceiling." This is just enough to hang a flat light, leaving at least 3", 7.5 cm, for safety and cooling.

Reflectors are optical systems, similar to camera lenses. Some lights are so sophisticated that they do use lenses. No one would dream of using wide angle lenses at the same distance as tele-lenses in side by side tests. For the same reason, installations should observe the manufacturer's and designer's recommendation, unless it proves to be erroneous. Lights of different design and character do not necessarily follow the same geometry. This is important in the selection of a new light source for existing quarters and can save much expense and embarrassment.

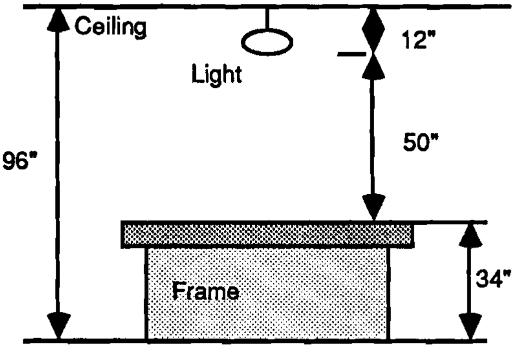


Illustration # 1

Light Installation

D. 3. Recognition of Environment.

Many darkrooms are disappearing, giving way to brighter areas with improved working conditions. With the use of higher powered lights, it is important that new challenges be met to make this change a full success.

Bright lights can be hard on the eyes and can fog sensitized materials in areas nearby. Enclosures or hoods should be used to contain the light to the exposure frame. Total enclosures may be preferrable in certain instances. Some like soft curtains, solid walls and moving doors. Others turn to "turn top" and "glass down" units. While the "lights from below units" can hardly be defeated, the overhead installations are not as successful in this aspect. Quite often they are not closed or used as intended to save time and energy. That renders the safety aspect useless.

Light hoods may be a preference in some cases. For most applications they will meet the safety requirements. They use no extra time or effort by the operator and still retain the airy and open atmosphere of the work area.

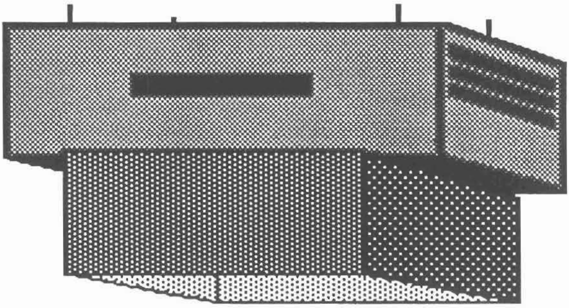


Illustration # 2
Protective Light Hood

Another aspect is the development of heat from high power lights. This becomes a problem that is inverse to the size of the room. The basic principle of physics known as the "Conservation of Energy" states that within any closed system, the energy remains constant. Energy can be changed from one form to another, but the total is constant as long as nothing is added or lost.

Consequently, if a certain amount of electrical energy is introduced into an area to expose materials, it will turn into a corresponding amount of heat. Electrical energy should be measured with a Watt meter. In many cases equipment operates with different degrees of efficiency, "Power Factor." The heat generated equals the TOTAL amount of energy introduced, no matter what equipment is operated with it, in terms of items discussed in this paper.

Specifically: One kilowatt-hour equals 3413 BTU, 859.8 kilogramm-calories. Therefore a 1 kW Quartz-Filament lamp used with an average exposure time of 18 seconds, twenty times per hour, one exposure every three minutes, is ON for a total of 360 seconds, 0.1 hour. Power consumption, disregarding surges, is 0.1 kW with a corresponding heat development of 341.3 BTU, 85.98 kilogramm-calories.

A 5 kW printing light, metal halide with shutter operation, may idle at a rating of 3 kW. Due to the reduced power, the power factor may be so poor, that the actual consumption is much higher. Assuming the rated power of 3 kW and assuming the same exposure duration and frequency as above, the total power consumed is: (0.9 x 3 kW) + (0.1 x 5 kW) = 3.2 kW or 10,922 BTU, 2751.4 kilogramm-calories. A more modern type of printing light, such as the Olite AL 50 which idles at 1 kW, develops 4778 BTU, 1203.7 kilogramm-calories under the same exposure conditions.

It is apparent from these figures that it is advisable to turn off a printing light when not in use, provide for evacuation of the excess heat or consider the extra energy in view of the total heating and cooling requirements. OLEC provides thermostatically controlled exhaust blowers for its line of high power printing lights.

D. 4. Reflectors, Large or Small.

The emitter, the lamp, is the center of the design pattern. Ideally, it is a point, radiating with equal intensity in every direction. Consider a candle. Far enough away it becomes a virtual "point." Moving our fingers in skillful manner between this source and a blank wall, we can produce clearly defined images at a distance. This is a very hard, sharp light source with a super wide angle of illumination. Therefore: the angle of coverage does not determine the "sharpness" of image.

Point sources not only produce sharp shadows, but also the opposite: specular highlights. That is why we use chandeliers in the dining room: to produce specular highlights that make food, silverware and china sparkle. On the other hand, in our living room we use large and soft lights. Here we do not look at inanimate objects but at people. Large light emitting areas reduce shadows, make them soft. Large lights reduce specular highlights. Large light emitting areas are kind to faces, reducing the appearance of wrinkles or shiny spots.

A single fluorescent lamp has a very short dimension across, but is extensive following its length. Raising an arm and holding it lengthwise, WITH the light, a sharp shadow is visible, ACROSS the axis of the light, the shadow can hardly be noticed.

The effective size of the Light Emitting Area (L) in terms of its Projected Image (P) through a pinhole will diminish in the inverse proportion to the distance. (D1 = Distance from light to original, D2 = Distance from original to exposure emulsion).

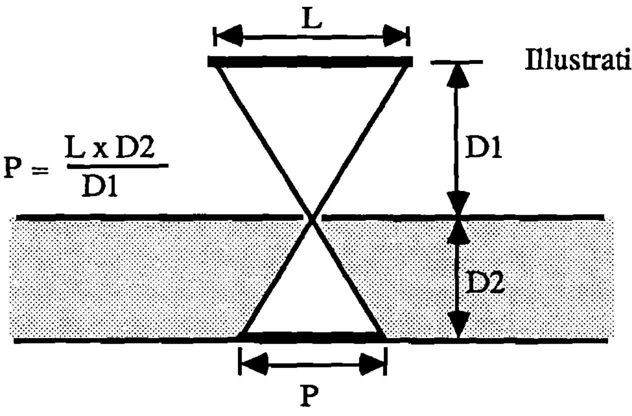


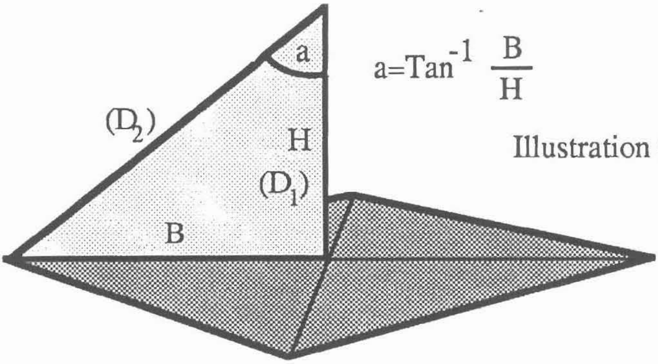
Illustration #3 - Pinhole

Therefore the actual exposure image of a reflector, light emitting area, measuring 10", 0.254 m across, at a distance of 40", 1.016 m, equals the effect of a reflector measuring 20", 0.508 m, at a distance of 80", 2.032 meter.

In contact exposures, halftones and line, sharp shadows and clearly defined lighted areas are demanded. Therefore it could be concluded that a very small point source mounted at great distance is the solution. Large reflectors at short distance seem to be the worst combination. Throughout the world that contention seems to be accepted, yet the very craftsmen that swear by it use the "worst combination" with excellent, high quality results. Some most exacting contact exposures are done on "glass down" frames with a distance no longer than 2', 0.61 m. There must be reasons, trade-offs or developments that defy the logical conclusions mentioned above.

D. 5. Angle of Illumination Off Axis.

In establishing the Angle of illumination off axis (a) two dimensions are known: the height (H) and the base, the diagonal of the area to be exposed. With the "Standard Frame" the diagonal measures 50", 1.27 m. (square root of 30 squared plus 40 squared). The base off axis (B) is half of the diagonal. The angle (a) therefore is:



$$a=\tan^{-1}\frac{B}{H}$$

Illustration #4 - Angle off Axis

For a height of 40", 1.016 m, and a base of 25", 0.635 m, the angle is 32 degree.

The angle of impact from the perpendicular onto the glass can so be established. As light, electromagnetic radiation, passes obliquely from one medium into another of different density, the velocity of propagation changes and with it the angle. The variation in direction is called REFRACTION. It is governed by a simple relation known as Snell's Law:

$$\sin a = n \times \sin g$$

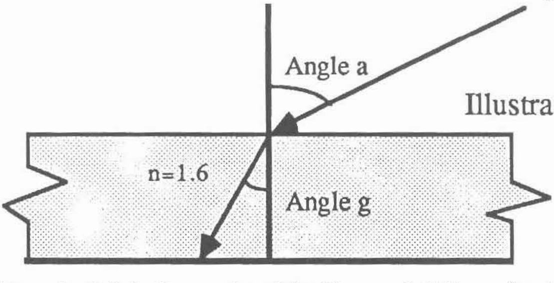


Illustration #5 - Refraction

In this formula "a" is the angle of incidence, "g" the refracted angle within the glass; "n" is the refractive index, a constant that is specific for different materials and equally applies for all angles of incidence. The refractive index for glass varies from 1.5 to 1.9, depending on the density. "Hard glass" used on some contact frames has a refractive index of about 1.6 which is used as a basis in this paper. Our sample assumed an angle of incidence of 32 degrees. The angle of refraction is calculated as follows:

n sin a = sin g; sin a = sin 32 = 0.5299; n = 1.6
0.5299/1.6 = 0.3312; Arc sin 0.3312 = 19.34; g = 19.34 degrees

The angle of light has changed from 32 degrees to 19.34 degrees, a considerable improvement. This would be equivalent to a light height of 71.23", 1.81 m. The inverse reaction or refraction will take place when the light exits the glass back into medium air.

But at this point, there is no air but film. Film has a refractive index very similar to glass and the light will therefore continue its straight path.

The same refraction applies to glass-less open faced frames. As soon as light changes medium, from air into the much denser film, it is refracted in the way described above.

D. 6. Effect of Angle on Exposure.

The effect the angle of illumination has on the actual result depends on the sensitized material and the methods used. Once an operator is familiar with the actual variation in size or other change, it becomes much easier to plan the work in such a way that the "fault" will not affect the result. For instance: should the size or dot change in a specified manner in an application where the size must match other exposures, all films should be exposed in the same position on the frame. In that way the error will affect all films equally and will not have an adverse effect. It should be established how much of an error is encountered with different height or angle of illumination.

D. 6a. Exposure E to E

Using the height of the light as a variable on a "Standard Frame" with a half-diagonal, the base, of 25", 0.635 m, and using a "true point source" for the discussion, a chart has been prepared to show the error in size incurred. It uses height as the distance to the point source, and shows the calculated elongation of the shadow of a dot.

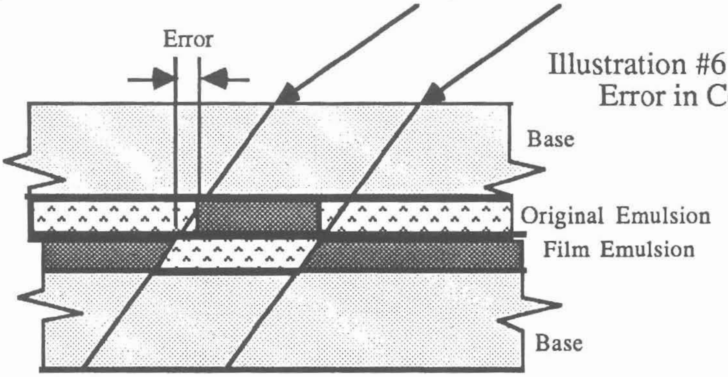
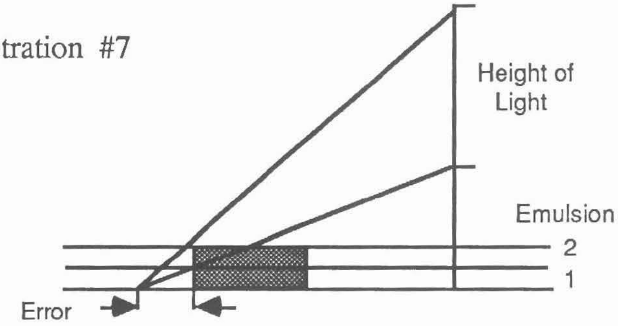


Illustration #6 - Dot Shadow, Error in Corner of Frame

Height		Light Angle		Thickness of Emulsion of Original					
				Error in millimeters			Error in Microns		
Inch	meter	On Glass	In Glass	.1	.2	.4	2.5	5	10
24	.61	46	27	.05	.10	.20	1.3	2.6	5.1
30	.76	40	24	.04	.09	.18	1.1	2.3	4.5
36	.91	35	21	.02	.08	.15	.96	1.9	3.8
40	1.02	32	19	.03	.07	.14	.86	1.7	3.4
48	1.22	28	17	.03	.06	.12	.76	1.5	3.1
60	1.52	23	14	.02	.05	.10	.64	1.3	2.6

Height is shown in inches and meters; the angle of incidence is shown as Glass Angle ON, the refracted angle as Glass Angle IN; the maximum elongation of a dot is shown for three thicknesses of emulsion of the original, measured in mil, one thousandth of an inch, and micron, one millionth of a meter.

Illustration #7



A very interesting fact becomes apparent from this chart. The thickness of emulsion of the original is of the greatest importance in the reproduction. In effect, it shows that a light mounted at 24", 0.61 m, will produce no more of an error on an emulsion thickness of .2 mil, 5 micron, than will a light mounted at 60", 1.52 m, height on an emulsion of .4 mil, 10 micron.

Emulsions of high sensitivity, such as used in darkrooms with low powered point sources are much thicker than today's contact films used "out of the darkroom" with high powered lights. That is why the reproduction quality has not suffered, using lights at much closer distances. These mathematical examples do not take into consideration that a certain amount of undercutting, penetration of the light into and diffusion within the photosensitive emulsion, will compensate for some of the error. It depends on the photosensitive emulsion just how far the light will penetrate under the original copy and effect an exposure. It varies greatly with different films.

D. 6b. Exposure B to E.

It is apparent that point lights will not be a serious problem in reproduction if exposures are made E to E, emulsion to emulsion. The next consideration is E to B or the use with spacers. The following chart shows how much a dot is moved from its original position with different spacing between original and photosensitive surface.

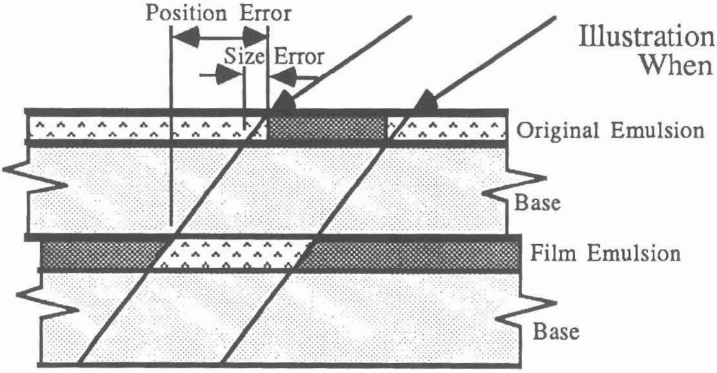


Illustration #8 Dot Shadow
When Spacer is used

Height		Light Angle		Thickness of Spacer					
				Shift in millimeters			Shift in Microns		
Inch	meter	On Glass	In Glass	2	4	8	51	102	203
24	.61	46	27	1.02	2.04	4.08	26.0	52.0	103.
30	.76	40	24	.89	1.78	3.56	22.7	45.4	90.4
36	.91	35	21	.77	1.54	3.07	19.6	39.6	77.4
40	1.02	32	19	.67	1.38	2.75	17.6	35.1	69.9
48	1.22	28	17	.61	1.22	2.45	15.6	31.2	62.1
60	1.52	23	14	.50	1.00	1.99	12.7	25.4	50.6

It becomes apparent that with overlays, exposures B to E or E to B the dots move substantially in the corner of the film. Considering that with a film thickness of 4 mil, 102 micron, the line in the very corner moves about 1.38 mil, 35.1 micron, with a light elevation of 40", 1.02 m. Raising the light to 60", 1.52 m, does not improve this situation much. In effect, the image still moves 1 mil, 25.4 micron.

Whenever such exposures other than E to E are used, it is important that a good register system is in place, and that all films to be matched be exposed in the same position, using the same space between original and final image.

D. 7. Effect of Reflector Size on Exposure.

There are no real point sources, point as defined to have no extension in any direction. All practical lights do have a definite size, larger with those using a reflector, smaller without reflectors. Reflectors, as optical systems, differ greatly. Some are of highly specular, others of more or less diffused material; some are round, others square, oblong or multifaceted. All will produce different effects and no universal rule will fit all.

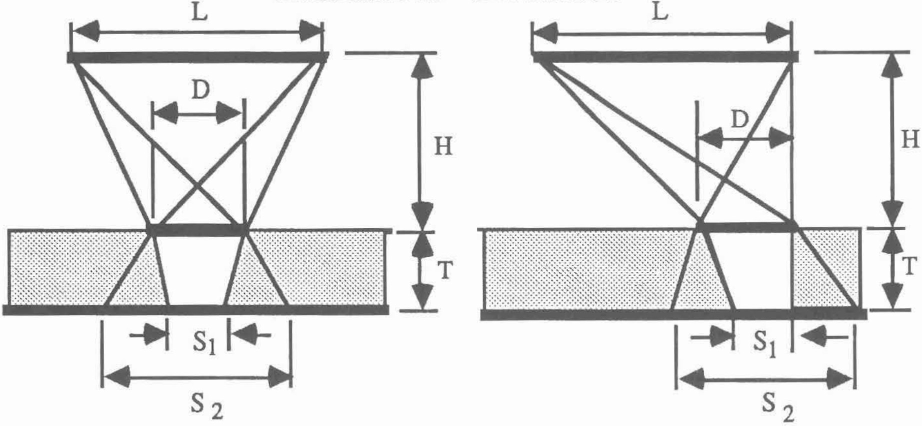
There is a basic observation that can help a user judge the result that can be expected, to some extent. Looking into a reflector from different angles will show a reflection from the lamp itself. Should the reflection be limited to one spot or area within the reflector only, the light emitting area will be small, corresponding primarily to the size of the lamp and the reflection. Should the reflection from the lamp be observed from different facets or should the reflector be constructed of pebbly material that reflects light in various directions, bouncing back and forth within the reflector itself, it stands to reason that the actual light emitting area is correspondingly large, in some cases as large as the total diameter of the reflector.

Well designed reflectors, for the application in contact exposures, should be as small as possible. Such reflectors try to limit the reflection to a small portion of the total reflector surface only. They must just supplement the prime illumination from the lamp itself, which will otherwise create a hot spot in the center, and increase the level of illumination around the edges and in the corners. The effective light emitting area is the prime source, plus that part of the reflector that is used to illuminate a particular spot, not necessarily the total reflector.

For the following discussion to establish the significance of the size of a reflector, we assume that the emittance or radiation from the source is homogeneous.

On exposures E to E the size of reflector has little effect in theory if the actual exposure were to take place on the surface of the sensitized material. In reality this is not the case, but the light penetrates the surface, will scatter and be reflected. Therefore large light emitters should only be used for spreads and chokes. Small lights will produce much sharper lines and harder dots.

Illustration #9 - Dot Shadow



Symbols	No Refraction	With Refraction Considered
D = Dot Size L = Light Source Size H = Height T = Thickness	$S_1 = \frac{TD + HD - TL}{H}$	$S_1 = D - 2T \tan\left[\sin^{-1}\left[\frac{1}{n}\sin\left[\tan^{-1}\frac{L-D}{2H}\right]\right]\right]$
S_1 = Shadow, Primary S_2 = Shadow, Secondary n = Index of Refraction	$S_2 = \frac{TD + HD + TL}{H}$	$S_2 = D + 2T \tan\left[\sin^{-1}\left[\frac{1}{n}\sin\left[\tan^{-1}\frac{L+D}{2H}\right]\right]\right]$

It becomes clear that large light emitting areas cannot be used to project fine detail with clear definition. They are quite appropriate for spreads and chokes. Important: the definition, "light emitting area," is not necessarily the total size of reflector, as discussed in other parts of this publication. The Olite AL 50 printing light with a reflector size of 10" x 10", .25 x .25 m, for instance, has a much smaller light emitting area and remarkable dot holding capability.

D. 8. Shape of Emitter.

Lamps are not true points but do have size and shape. Most are elongated, some are round or close to it. All emit light, electromagnetic radiation, in different directions.

Filament lamps with clear outer cover generally consist of a coiled tungsten wire, wound in a complex structure, carefully held in suspension. Each small part of the wire, once it is energized, radiates light. It can be assumed that this radiation is of equal intensity all along the wire. Since this wire is wound and often double wound, the integrated radiation can project unevenly, unless it is used at a great distance (relative to its size) or in a carefully designed reflector. A distinct pattern can be detected with the use of some lamps.

Gas discharge lamps of low, medium and high pressure radiate along the path of the energy flow. Just as lightning during a thunderstorm, this radiant arc wanders constantly and at times develops a preferred pattern. It is not homogeneous throughout the expanse of the gas filled envelope. It becomes clear that the secondary radiator, the reflector, must be forgiving to some extent, otherwise these patterns will be reproduced. It would render the light unusable for the photographic applications in the Graphic Arts.

Lights radiate in all directions unless there is an obstruction, such as a socket or electrode. Considering a point source without reflector at a height of 60", on a "Standard Frame," radiating in all directions, only less than 10% of the total light output is utilized.

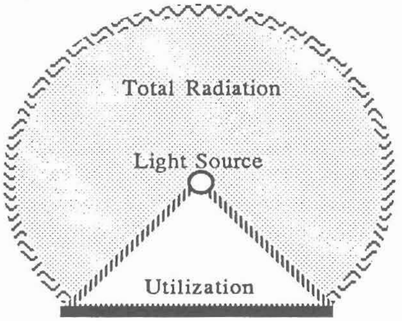
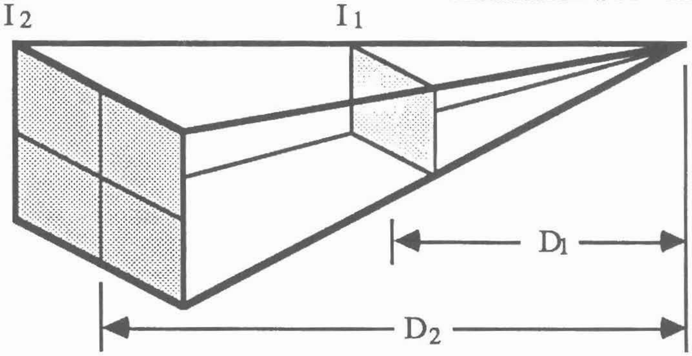


Illustration # 10 - Light without reflector

Using a reflector, much of the light that is radiated into other directions, rather than onto the frame, can be redirected and put to use. But now the light emitting area has increased manifold and that may not always be desirable. Light emission can be redirected towards the outer edges for increased evenness. There are certain factors that cause light falloff unless a properly designed reflector or other optical system is used. Here are the reasons:

INVERSE SQUARE LAW: Light intensity diminishes by the square of the distance. "I" is light intensity; "D" is the distance.

Illustration #11 - Inverse Square Law



$$\frac{I_1}{D_2^2} = \frac{I_2}{D_1^2}$$

To calculate the decrease of intensity at distance D2, considering the intensity at distance D1 to be "1," the formula is:

$$I_2 = (D_1 / D_2)^2$$

The function D1 / D2 equals the cosine of angle "a." Therefore the reduction of light intensity to a given point along the outside of the frame, compared to the center, is equal to the cosine of "a" squared.

Cosine effect: If the angle of illumination is moved from the perpendicular without change of distance, then the intensity is reduced according to the cosine of that angle. "I" is the Intensity in the corner, "L" the intensity of the Light in the center, "a" the angle of light off Axis: $I = L \times \text{cosine } a$

The inverse square law and the cosine effect are combined to calculate the reduction of light intensity in the corner of the area to be exposed:

$$I_2 = I_1 \times (\text{cosine } a)^3$$

For a practical example: the point light is mounted at 5', 60", 1.52 m, and the falloff of light intensity in the corners of a "Standard Frame," with a diagonal of 50", 1.27 m, should be established. To establish the angle "a" the half base is divided by the height: 25 : 60 = 0.417. This is the tangent of the angle off the perpendicular, 22.5 degrees. It is not taking into consideration the reflection off the glass at an angle of 22.5 degrees. The cosine of 22.5 degrees = 0.923, and raised to the third power, 0.7865. That number represents the light intensity at the corner in relationship to the center, a falloff of more than 21 %. This does not consider the reflection off the glass at that angle.

Another interesting aspect concerns elongated lamps. These lamps emit light radially along the axis, but nearly all of it is blocked at the ends, which have very little area anyway. In reflector design, it is very easy to direct the radiation from the sides, to the outer ends of the frame. There is no light from the ends of the lamp that could be directed. Therefore elongated lamps should be mounted ACROSS the frame, not lengthwise! That sure will surprise most users and even manufacturers. Tests on the OLEC printing lights showed without a question that this is the case. There goes another "golden rule."

Mounting lamps across the frame offers another advantage. The emitter remains as the primary source of light, the reflector being a secondary supplement to even out the intensity over the whole area. The size of the prime light emitting area, as perceived by the photosensitive material, is much shorter across the lamp than along the length. The error will be greater with the longer than the shorter dimension. The greater error should be directed to the short side of the frame, the smaller error to the farthest distance.

9. Further Comments.

Reflector design is one of the very expensive, time consuming and frustrating tasks in the engineering department. Much of the design work is done on computers, but it always comes right down to testing for final confirmation. In the search for the ultimate in reflector design, some very interesting calls are received by OLEC. With the change from other lights to Olite, deficiencies in the operation can become apparent. Time and again the lights are blamed for pinholing or similar exposure problems, simply because new technology lights project a more defined image.

In reality, the most ideal light source, based on theories, can be so impractical that it may well be rejected. It is important to deal with the result that can be achieved within economically feasible boundaries, yet still producing the quality expected by a discriminating and paying customer.

E. The Three Most Commonly Used Light Sources.

The most popular light sources used for Contact Exposures are Quartz-Filament, Fluorescent and Mercury-Halide lights. Others are discussed briefly in part "H."

E. 1. Quartz Filament Lights.

With the introduction of Quartz lamps, many lights have changed to adapt this new technology. Quartz lamps are more concentrated and feature a longer life without appreciable deterioration in power or color temperature. Most commonly used lamps are in the range from 100 to 1000 Watt. Filament lamps have a few common features that make them different from Gas Discharge lamps:

a. Ambient temperature, heating or cooling has little effect on light output and color.
b. Line voltage changes cause substantial variations in light output and color.
c. Lamps have a quick, repeatable warmup, generally under 1/20 of a second for consistently repeatable exposures, without shutter or "idle."

The lamps vary in light output through variations in the applied voltage according to the following formula.

L = Light Output, V_A = Applied Voltage, V_D = Design Voltage

$$L = (V_A / V_D)^{3.5}$$

In application, with an applied voltage of 100 V and a lamp designed for 120 V, the actual voltage has dropped to 83.33%; taken to the 3.5th power we find that the light output is reduced to 52.8%. That does not take into consideration the drop in color temperature, from 3400 to 3150, from 3200 to well under 3000 degrees Kelvin. There is little blue and violet left in the light to expose blue sensitive film.

A very interesting aspect of this formula is the fact that it applies to lamps of different power levels equally, as long as they are connected to the same power line. If a photo sensor is used for light integration, it can be used on any lamp connected to the same circuit and will track changes in output just as accurately as if it were looking at the prime source. That is the technical background for the successful Olite photocell boxes that operate consistently with a secondary light source as signal for integration.

Lamp life is the ratio between Applied Voltage and Design Voltage to the 12th power according to the following:

$$LL = (V_A / V_D)^{12}$$

Different types of voltage regulators have been used in the trade, magnetic and electronic. Mostly they prove quite inadequate. Integrators are often used in addition, which defeats the purpose, but proves the point. Most integrators or similar instruments should NOT be connected to a voltage stabilizing unit due to the phase shift and distortion of the sine wave! (There are a few exceptions but they are expensive). OLEC has developed technology that can stabilize light output to a very fine degree but has not found a market yet.

Low voltage lamps have higher efficacy, light output from a given electrical energy input. Therefore low voltage lamps are used in the lower wattage ranges such as the 100

Watt "point light" for darkrooms. Conventional lights used 20 V lamps with relatively short life. New Quartz lamps operate on as little as 12 V with higher output and life expectancy.

In higher wattage, single and double ended lamps are used in the range from 600 to 1000 Watt, ranging from 3200 to 3400 degrees Kelvin. Tap switch boxes are available for OLEC "CT" to reduce the high power level and make such lights more universal in their application. It should be remembered that the reduction of power also reduces color temperature. Great variations in intensity and color caused by different tap settings, rather than line fluctuations, cannot be accurately compensated for by an integrator. The sensor combined with a secondary lamp becomes an excellent solution.

Lamps of 3400 degree Kelvin, in the high blue and UV range, should be used with caution. They find application where short exposures are demanded and line voltage is low. Due to the higher temperature of the lamp, it is important that the light unit be mounted in a safe distance from any ceiling and that the flow of cooling air not be impeded by any enclosure. It is also important that these lamps be treated with special care. They must not be touched with bare hands nor should they be exposed to excessive mechanical stress. Single ended lamps of this type should not be mounted base up. It is also important that the lamps be used within the manufacturer's specifications. For long lamps it generally means a horizontal position. The position of the base on single ended lamps is often critical. Never use any replacement lamps other than those recommended by the light manufacturer.

E. 1a. "Point Light" Sources.

The term "Point Light" is often used loosely without proper definition. For theoretical exercises we use the term as a true point, without any dimension. In practical application any light does have a dimension. To keep the size as small as possible, a compact source is used, generally of very low power, such as 100 Watt. To further contain the size, no reflector is included in the fixture.

That means that such sources are directly affected by the Inverse Square Law and the Cosine Effect. A severe falloff to the corners is the result, as per our example above (D.8.), 21% on a "Standard Frame" with a light height of 60", 1.5 m. This can be reduced by raising the light to much greater height. In that case little of the intensity remains and films of high sensitivity must be used. Consequently the definition of the emulsion suffers and the problems of fogging, working in near darkness, etc., become apparent.

There are applications where such sources are still used to satisfy specific demands, such as with numerous overlays, where the collimation of the light is of importance. While truly collimated lights within confined areas and of high power levels are within the range of possibility, there is insufficient demand to warrant engineering investment.

E. 1b. Reflector Lights.

Height restrictions in many quarters make the use of point lights impractical. Advantages are realized by moving out of the darkroom. With new and thin emulsions of lower sensitivity and high definition, the tiny point light can be abandoned in favor of efficient, high power lights using lamps of small size with reflectors that increase the level of illumination in the corners. Often the evenness of these lights outperforms conventional point sources used at reasonable height.

When the new out-of-the-darkroom films were introduced, no Quartz lights had been manufactured that would illuminate a vacuum frame evenly, in effect would radiate more light towards the outside than to the center. The first lights in use were movie and photographic fixtures. It was a challenge to produce a light that would do justice to the demands, yet be safe and designed with the limited ceiling height in mind.

Such a light, the Olite AL 1KT for instance, uses a double ended lamp with a prime emitter of about .750" x .220", 19 x 5.6 mm. It becomes the prime light emitting area for calculations. The reflector, like most reflectors designed by OLEC, does not use pebbly, specular aluminum. Pebbly surfaces, while featuring high reflectivity, bounce light in many directions, eventually making the whole reflector area a light emitter.

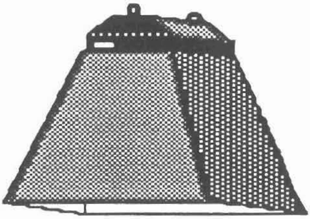


Illustration # 12
Quartz Light with Hood

The reflector material preferred by OLEC is of a satin type with high reflectivity, but much improved directional features. It can direct light more precisely. A cross effect is used, for the highest efficiency under the circumstances, directing the reflected light to the opposite corner with a minimum increase in light emitting area. The lamp should be mounted across the frame, not lengthwise (see explanation above, D.8.).

E. 2. Fluorescent Lights.

Fluorescent lights use low pressure mercury discharge lamps with fluorescent covering. They are available with different spectral emission for use in the Graphic Arts. Due to the low emission per area, large lamps and light units are necessary for exposure purposes. It is not feasible to design efficient reflectors other than large radiators. Such lights are very efficient in their own way. Fluorescent tubes can have high efficacy if the appropriate spectral output is used. Exposures are short with relatively little power input and a low amount of heat developed. The efficiency is based on the close distance at which the light is used, guaranteeing minimal loss of energy. The most common use for fluorescent lights is for the exposure of proofing material and for spreads and chokes, dry dot etching. In the latter application the success is based on the use of omnidirectional light to enhance undercutting from all sides equally. Too little use is made of this excellent exposure tool.

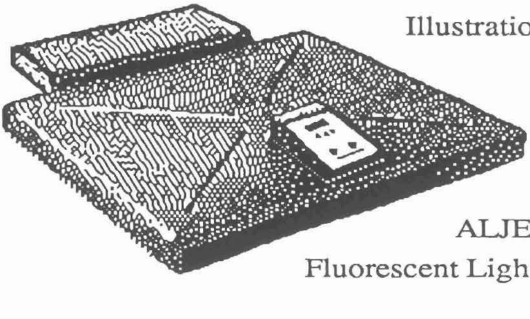


Illustration # 13

ALJEN
Fluorescent Light Unit

E. 3. Mercury Halide Lights - Printing Lights.

Mercury Halide Lights are referred to as Printing Lights. Their primary use was the exposure of printing plates, until the "out of the darkroom" films and papers and proofing materials arrived. The lamps are medium pressure Mercury Vapor doped with a variety of additives, such as Iron, Cobalt, Lead and Gallium Iodide. The elongated lamps are generally filled to a pressure of approximately 1/5 of atmospheric when cold. In a hot condition they develop a maximum of well under 5 times atmospheric. The pressure in shorter arc lamps is considerably higher, as high as 17 times atmospheric pressure.

The lamp envelope is filled with an inert gas such as Argon. Some lamps use Xenon to give the impression of instant start. Argon has little radiation of light, while Xenon, quite a bit more expensive, appears very bright to the eye instantly. Such radiation has relatively little effect on the sensitive surfaces in the UV region. The fill gas is ionized and will heat up the inside of the Quartz envelope. Soon the Mercury in the enclosure will vaporize and induce further energy flow and heat generation. Mercury, once in a gaseous state, does emit spectral lines that are more suitable for UV exposures. The main mercury lines are 365.5, some 404.7 and 435.8, 546.1 and 578 nm. As the temperature rises further, other additives vaporize at different points, adding their own spectral lines to the increasing mix in radiation.

It becomes apparent that during the warmup time the color of the emission changes several times. It also becomes apparent that the heating up period will take time, usually from 20 seconds to 3 minutes, before the lamp will stabilize and accurate exposure timing can begin. That warmup period is not a repeatable constant such as with a tungsten filament lamp. It greatly depends on the condition of the lamp from previous exposures, ambient temperature, etc.

Lamp temperatures are difficult to measure and special lamps with built-in thermocouples have been produced for OLEC to be used in engineering. This temperature range is very critical for lamp life and performance. Slight changes in lamp temperature can make considerable difference in the color of radiation as well as total output. Interestingly enough, overheated lamps loose efficiency, just as underheated ones. Manufacturers' recommended lamp temperatures for Halide lamps, quoted in degree Celsius, are as follows:

Bulb Temperature:	Seal Temperature:
Max 950 ° Min 750 °	350 °

The lamp temperature is a more important factor in output stability than incoming line voltage variation. Ballasts and capacitors, used in some power supply circuitry, tend to equalize the effect of fluctuations. For general information, the formula for gas discharge lamps is:

L = Light Intensity, V_A = Applied Voltage, V_D = Design Voltage.

$$L = (V_A / V_D)^2$$

F. Reflector Design for Printing Lights.

Halide lamps with precise temperature and cooling requirements obviously need careful attention in engineering. That makes the design of the reflector difficult and more expensive. Here are some of the considerations:

F. 1. Lamp Mounting, Mechanical and Electrical.

At power levels up to 5 kW, with the corresponding heat and high voltage used in operation and starting cycles, the electrical connections must be of heavy duty design. With the relatively high price of the lamp and its fragile nature, the mechanical holders should be strong, yet tender. Time and again I was called in to service lights and change lamps. It sure changed my attitude toward design. Hanging on to a sprinkler pipe with one hand, leaning over an expensive piece of glass on a large vacuum frame, trying to change a lamp with the other hand, is an experience that every design engineer should be subjected to. With that thought in mind, I present this rather important point:

Electrical contacts can either directly connect the lamp contacts with springs, or connect to a lead wire with an independent, nonelectrical mounting for the lamp only. Due to the very high levels of power and drastic temperature changes, OLEC opted for the latter. The lead wire terminals must be designed to heat up and cool down in regular intervals, therefore, springs need to be used that will not tire. This can be done with faston or screw connections.

The illustration shows the standoff of a lamp that uses screw terminal, electrical connections with spring washers that can be handled with one hand. The lamp is held with separate clips. In this way the problem of lamp change with one hand is minimized.

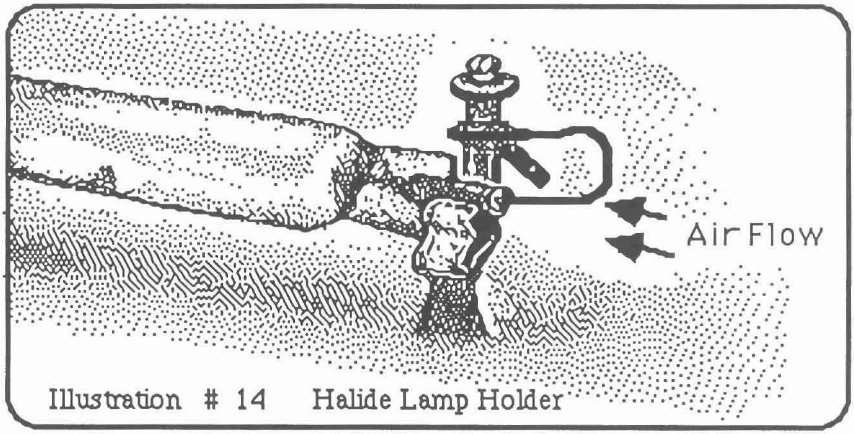


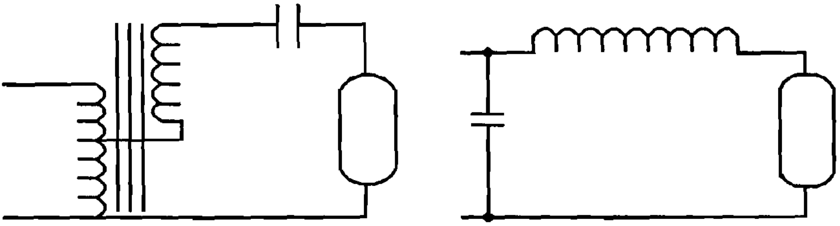
Illustration # 14 Halide Lamp Holder

F. 2. Lamp Environment.

Lamps are designed to live within carefully defined parameters. Given that kind of environment, they live a long life. In careful tests within the OLEC testing department, verified by field use, the lamp life has been established to far exceed the manufacturers' claims or generally accepted limits. The life expectancy depends on ballasting, start-up current, temperature control, standby current and the amount of actual exposure time.

Conventional systems use reactive type ballasting, inexpensive, uncomplicated yet not complimentary to lamps or power lines. High power surges during startup cycle, demanding heavier input power, and the low power factor, especially at standby power levels, are a high price to pay in the long run. OLEC chose CW, constant wattage ballasting and was able to decrease warmup time without high start-up current or power surges. A power factor of .99 to 1.0 at full 5 kW is achieved through careful tuning. This saves lamp life and power consumption.

Illustration # 15 - Lamp Ballast Types



Constant Wattage Ballast Reactive Ballast

F. 2a. Cooling of the Lamp.

There is no more important aspect for lamp life, consistency of light, and UV output than cooling. From the lamp manufacturers' specifications, listed above (E.3.), it becomes apparent that the lamp center must be kept at a precisely specified temperature range. The ends of the lamp, the seals, should be cooled well. To accomplish this, the main stream of cooling air should be directed onto the seals, little onto the center body of the lamp. A smaller and carefully proportioned amount of cooling is necessary in the center to avoid overheat. Should the lamp overheat, it may bulge and even explode, due to excessive pressure created within the envelope.

One solution to this prime design parameter, followed by the OLEC design team, is to cool the lamps axially, from the ends, to assure relatively even temperature around the outside. As the air heats up, it expands. With the cooling air directed at the lamp from both ends, turbulence develops in the center, assuring reduced cooling capacity, precisely the desired effect. This system also keeps the lamp mounting holders and electrical connections within reasonable temperature ranges. The heat sensors are mounted in the path of the cooling air. Being next to the prime heat generator, these thermo-switches will sense the failure of a cooling blower immediately and shut down the supply power to the lamp.

F. 2b. Controlled Lamp Temperature.

The optimum level of radiant output and efficacy will be reached when the Halide lamp is operated within the manufacturers' temperature limits. Operation below the limit, caused by overcooling, will prevent some of the additives to vaporize. It reduces output considerably and changes the radiation spectrum. Overheating also causes a reduction in radiant output. Light units heat up during times of heavy use. Add changes in ambient temperature and together that can make a substantial difference in lamp heat. The change of intensity, from 5 kW to 1 kW and an intermediate step of 2 kW can be a challenge for designers, trying to keep a constant heat plateau.

-One of the great advances in reflector and light design is the demand cooling of the lamp introduced by OLEC. The electronic servo system senses lamp temperature and continuously varies the speed of cooling blowers to accommodate the precise requirement for air flow. This, more than any other feature, stabilizes output and color of the light and greatly enhances lamp life. During the warmup cycle, when the lamp does not want to be cooled, the blowers are off. After shutdown, the blowers automatically switch to high speed for a predetermined period of time to facilitate fast restrike.

F. 3. Exposure Control.

Quality depends on precise control of the exposure. Timers or integrators turn the light on and off; that is if the light can be turned on or off. There is no difficulty with filament or gas filled lamps. Mercury Vapor and Halide lamps have a warmup period that can be as long as several minutes, and a restrike period that can be even longer. Ordinary timing methods are just not adequate for such lighting.

F. 3a. Quick Start.

In 1974 the Chadwick Helmuth Company introduced a quick-start/instant-restrike system for Mercury Vapor and similar lights, a major development in the lighting industry. It was adapted to some Graphic Arts equipment and was labeled "instant start." That term could be defended, since nearly all lamps start instantly but at very low output. With the Chadwick-Helmuth patent, the lamps restrike instantly, to full power, while still hot. That is the real advantage of the system. The patent was soon plagiarized or copied by numerous manufacturers.

Fact is that the EXPOSURE does NOT start instantly on "instant start" units. All Halide lamps go through a cycle of heating the gases and additives in the tube of the bulb itself (details under 3. above). During that cycle the emitted radiation changes in intensity and color in a number of steps. Some of these changes are subtle and hardly noticeable, because the UV content is beyond the spectral sensitivity of the eye. But they sure make a difference in the exposure of UV or violet sensitive material.

Warmup periods can be incorporated into the basic exposure time, provided they are consistent and repeatable. That is not the case with "instant start" units. The actual time to full exposure intensity will vary from exposure to exposure, and the difference can be substantial, in the range of 5 to 20 seconds. That may not make much of a difference on plates or materials with plenty of latitude, with exposures longer than a minute. It is just not acceptable on precise timing with shorter exposures.

Light integrators are of some help under those cicumstances but cannot possibly match the precise spectral sensitivity of the many different materials used. Further than that, the integrator starts counting with low spectral energy levels that are beyond the toe value of the sensitivity of the material. By the time the peak intensity is reached and the actual exposure starts, the integrator has already logged a good deal of time.

The quick start units usually consume extra power during every starting cycle. This can soon negate any advantage in power savings, provided that a shutter controlled light can be turned off during periods it is not used. New designs make it feasible to save the idling power. The Olite 5 kW light is up to full readiness within less than 40 seconds.

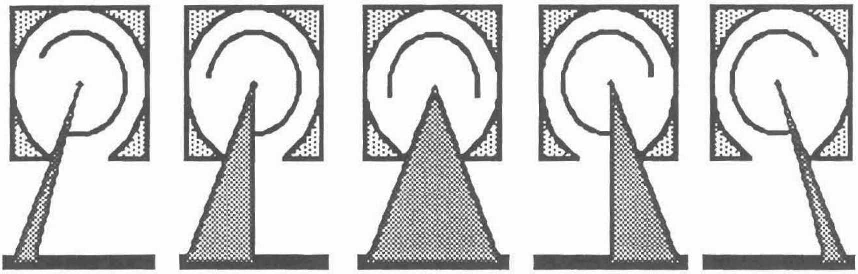
F. 3b. Shutter.

One of the reasons for companies to scramble for an alternative to shutter type lights was the great number of repairs incurred and the corresponding down time. The design of the shutter must fit with the lamp mounting, the electrical wiring, the cooling and the reflector into the same small space within the light housing. That area is exposed to heat and UV rays. No easy task by any means.

Conventional shutters use reciprocal action. Such designs are reasonable for limited use, but are subject to excessive wear in the Graphic Arts, especially in busy places or with step and repeat machines, that least can afford down time.

Being cognizant of the demands, I headed a design team to develop a rotary shutter. It has been incorporated into the Olite printing lights and in repeated tests has stood up to over a million operations without appreciable wear. Opening and closing in the same direction at precise speed, it can be used to accurately time exposures as short as one second. Times shorter than two seconds are not considered a practical application in the Graphic Arts, but the technology is here to do it. Shutter breakdowns and repairs no longer need to be a source of concern.

Illustration # 16 - Rotary Shutter



F. 4. Optical Design.

The reason for a reflector is the optical capability to redirect the light emission from the lamp, which would otherwise be lost into the housing, and reflect it accurately to the areas that would otherwise show too much falloff (see more detailed explanation under D.4.). It should avoid causing an increase of the size of the light emitting area. Large, multifaceted or omnidirectional reflectors tend to undercut the image. In small reflectors it is difficult to accommodate lamp, shutter and cooling.

The reflector design developed, favored and used by the OLEC engineering team employs a crossover pattern. In this reflector the reflecting surface on each side is as close as possible to the prime emitter, the lamp, and in this way the effective light emitting area is kept small. It is the reason for the exceptional dot holding ability of this source right into the very corners of a Standard Frame.

F. 5. Sensor for Light Integration.

Light integration should be used in all applications where precise exposure timing is a requirement. Light integration depends on accurate data input. Well designed modern digital circuitry is steady and not subject to variations or fluctuations. If inconsistencies do arise, they can invariably be traced to the input. The input into the digital counting and calculating circuitry of the integrator is generated by the analog photosensor and the analog to digital converter. The photocell should be mounted within the area of prime or reflected emission of the UV source. Secondary sensing lights, as used with filament lamps, are unsuitable.

Recently I visited a showroom where equipment was being assembled for a customer, a large frame, powerful printing light and a fine integrator. The photocell was mounted on the frame, "where it belongs." When questioned why the photocell "belonged" there, it was quickly pointed out that the light was to be moved up and down. Suggesting that this was rather illogical, I was asked to explain: Two errors had been committed in planning this installation.

1. The intention was to lower the light to cover a smaller area with higher light intensity. As the prime cone of illumination becomes smaller the photocell finds itself positioned outside of this cone. It was not moved in the same geometric ratio. In effect, when the photosensitive material sees more light for a shorter exposure, the photocell sees less and the integrated units run slower for a much longer time. This is the exact opposite of the required effect. Even if the light were not moved up or down, the photocell still sets at the edge of the cone of light. In the center, the light generally shows great evenness, but not at the edge. Here the falloff is very rapid. The slightest movement of the light may have little effect within the exposure area itself, but it certainly affects the photocell and the corresponding exposure time greatly.

Point number two is just as important. Who decreed that the photocell "must" be on the edge of the vacuum frame? This seems to be a common assumption without base in fact. The emission from the lamp may vary for a number of different reasons as discussed above. If it does, such variation in intensity is exactly the same, no matter where a reading is taken, near the lamp or far away. If the light increases 10% near the lamp it will not increase by 15% or maybe only 5% on the frame. What could possibly get in the way, unless there is dense fog.

A photocell mounted on the edge of the frame is exposed to all kinds of problems: the most common is a reflective curtain that may hang at a different distance or with a differently curved fold with every exposure; the photocell is constantly moved and particles inside may come loose and shift, or the wire may eventually fray and break; dirt may gradually build up which is not noticed until one day someone cleans the top, removes the dust and consequently changes all exposure values; other lights nearby or a high level of ambient light can change the intensity the cell will see; last but not least, someone with light clothing standing near may reflect additional light onto the photocell. I have seen all of these problems, and they all cause inconsistent exposures. Without a doubt the integrator gets the blame, and that applies to all kinds of integrators.

Mounting the photocell near the lamp, into the light housing, seems to me as one of the most logical solutions; however, there are some serious warnings. Photocells are affected by heat. OLEC has developed proprietary circuitry that greatly reduces that effect within a reasonable range, but does not eliminate it. Therefore the mount must be near the cool air flow of the blower. The cell housing should be constructed in such a way that it will dissipate any heat collected. The intensity of UV at such a short range can be considerable and should be attenuated through neutral density filters or reflected light should be used. In OLEC lights, the sensors are mounted in the cold air plenum.

F. 6. Light Trapping.

Halide lights develop light and UV of very high intensity. During exposure, but especially during long periods of standby, there should not be light leaks. The housing itself must be tight to avoid fogging material in the immediate and adjacent areas. The shutter should be real tight on lights used with exposures of variable intensity, to make them suitable for both plates and sensitive films.

F. 7. Safety and Comfort.

Light trapping becomes a safety issue. Following are some details to define UV and the safety hazards that may be connected with its use. There are also many beneficial effects to working in bright areas with a certain amount of the "right" UV. The germicidal effect, for instance, can rid the air of bacteria and is used for that purpose extensively in hospitals. Exposure of the skin to UV produces Vitamin D, necessary for the formation of bones and teeth. Sunlight contains an abundance of UV and the negative effects of overexposure have become well known, primarily sunburn, sore eyes and headaches. This is caused by the erythemal energy that penetrates the natural filter of Ozone in the upper layers of the atmosphere.

Halide lamps produce such wavelengths, and unless certain measures are taken to protect the operator, can be harmful. In most lamps, certainly in all the lamps used by OLEC for the Graphic Arts, a filter Quartz is used that will not permit penetration of wavelengths lower than 275 nm. A typical spectral energy graph for the Olite L 1250 lamp manufactured by Philips is displayed below. Very little energy is generated in the region of 275 - 315 nm and more than 85% of the radiation under 315 nm is filtered out by the safety glass. That glass features an interlock switch to defeat operation should it be removed.

Relative Spectral Power Distribution - L 1250 Halide Lamp

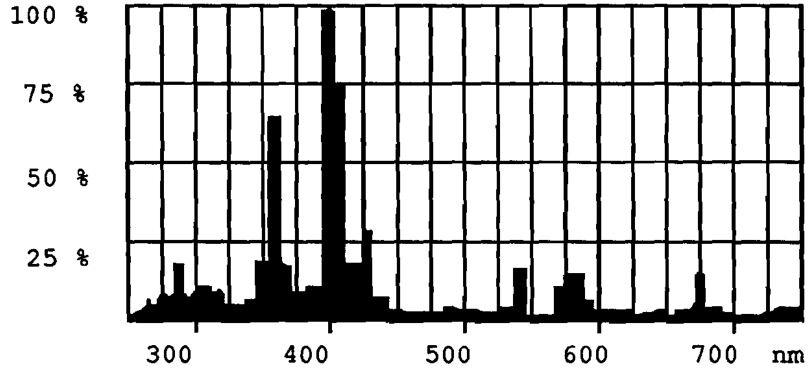


Illustration # 17

A curve that represents the relative effect of different wavelengths as cause of erythema, the excessive reddening of the skin, is shown (Illustration: #18). It becomes apparent that without the safety glass in the light unit, the radiation from the lamp emits a small amount of energy in the region of sensitivity of the skin. NIOSH, the National Institute for Occupational Safety and Health, has recommended standards for exposure to Ultra Violet, UV radiation. In this recommendation the UV spectrum is divided into two regions, the 315 to 400 nm or long wave region, referred to also as NEAR UV or "UV A," and the region from 315 to 200 nm or short and middle wave region, also referred to as FAR UV or "UV B." The division is made at 315 nm because the difference in the potential hazard is so great for the two regions.

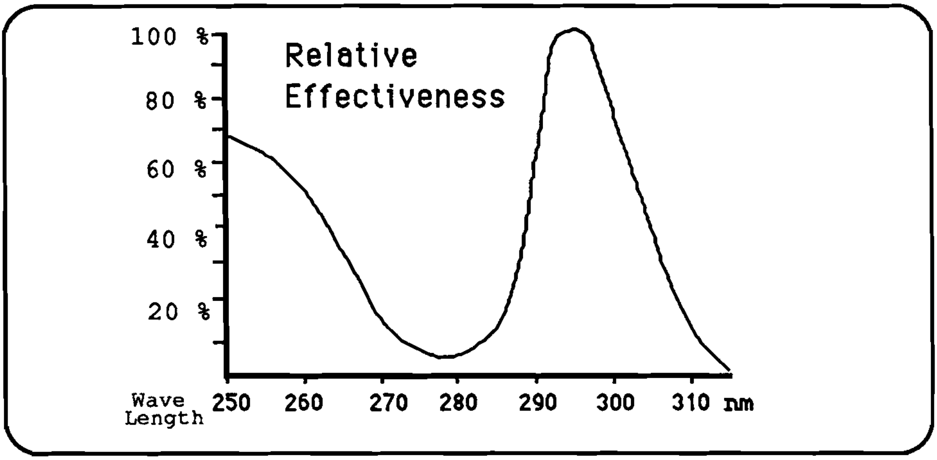


Illustration # 18 - Standard Curve: Sensitivity of Skin to UV

For the UV A, it is recommended that the total radiant incidence on unprotected skin and eyes should not exceed 1.0 milliWatt per square centimeter for periods longer than 1000 seconds. If the incidence is less than 1.0 mW/square cm, there is no time limit. If it is more, the time should be reduced so that the total dose does not exceed 1000 mW/square cm within a 24 hour period. To put this into perspective, the center intensity of a 5 kW printing light on a Standard Frame is around 5 mW/square cm. With an appropriate hood attached to the light, a little skirt that will prevent the stray light from the glass or reflector sideways, the area outside the frame is well below the 1 mW/square cm safe level of UV. Even the reflection from the cover glass on the frame will not exceed the safe level but one must not stare into that reflection to observe the lamp. Observation and inspection of a lamp in operation should only be attempted with approved welding goggles with all necessary safety precautions. It can be even more dangerous than looking into the sun.

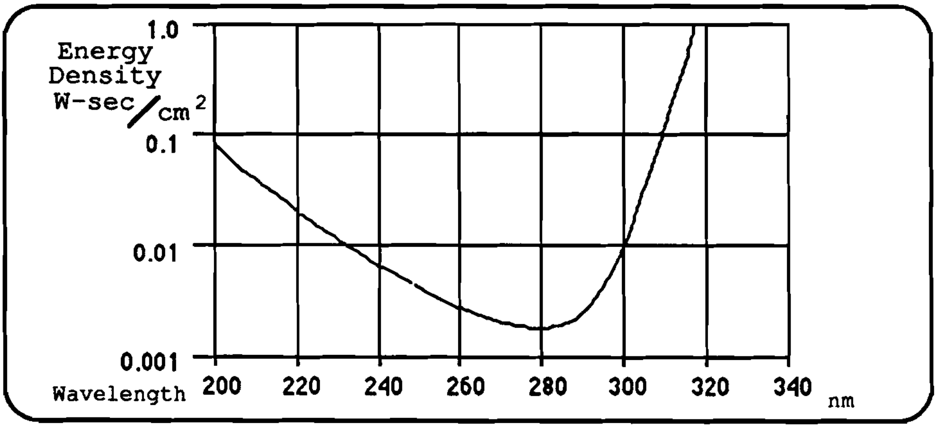


Illustration # 19 - Recommended UV Radiation Exposure Standard

For the 315 to 200 nm region, the NIOSH recommendations are more complicated. The recommended UV Radiation Exposure Standard is shown in the graph (Illustration: #19). The vertical axis represents the allowable dose the operator may receive in a 24 hour period. The horizontal axis is the wavelength of the light incident on skin or eyes. For example: to establish the Permissible Exposure Time, PET, or the 297 nm line of the spectrum, the chart indicates 10 mW-sec/cm squared; with an intensity reading of 0.05 mW/cm squared, we calculate the PET as follows:

$$PET = \frac{6.0}{0.05} = 120 \text{ Seconds}$$

That means that the total exposure during a 24 hour period must not exceed 2 minutes. Very little of this energy is radiated by most lamps and more than 85% is absorbed by the safety glass. In well designed light housings, there is little concern. Such emission is only apparent during actual exposure time.

Should there be leaks of radiation from the rear of the housing, where the energy is permitted to escape without the safety shield the glass provides, this can be dangerous to the operator. Considering the long period of exposure during a working day with a lamp idling and protective enclosures open, even very low levels of radiation can add up to dangerous levels.

The above is a recommendation for the maximum level of exposure to UV. It is my suggestion that operators use their own judgment as well. Some people love the outdoors and thrive on sunshine. They will have little or no problem with safe UV lights. Others are exceptionally sensitive to the sun because of their basic body chemistry or certain types of medication they may be taking. They should protect themselves by using enclosures, UV reflective or absorbing coating on their regular glasses, or safety glasses such as are worn by skiers, long shirt sleeves or a sun blocking lotion. Safety practices are not only wise but increase productivity.

A further consideration involves productivity in terms of operator comfort. Many Graphic Arts Shops are air conditioned. It has been realized that productivity slows in hot and humid places. As is explained in detail above (D.3.), shutter type printing lights can add to temperature and discomfort due to idling. Good equipment design will provide for the exhaust of hot cooling air.

G. Determination of Quality of Illumination.

In this paper a lot of ideal conditions have been described. There is also the suggestion that reality demands practical solutions that are economically feasible. There are no perfect solutions. Once equipment is in place it is important to make the best of it. When chosing to replace or add new equipment, it should be carefully evaluated and COMPARED with existing or competitive units.

G. 1. Evenness.

Evenness is difficult to attain from a small source, especially with consideration of the many varied applications. The required level of evenness has much to do with the type of sensitized material used and quality expected. Some of the "rules of thumb," such as 13% to be the maximum falloff that can be tolerated, just cannot be defended as being applicable in all situations. As a matter of fact, we showed above, (D.8.), that even at 5' height, 1.5 m, a point light will have a 21% falloff, not considering reflection from film and glass. Evenness should be tested carefully and realistically.

G. 1a. Tests.

Exposure tests should be conducted under actual working conditions, with the photosensitive material that will be used. This is not only the best but really the only way such tests become meaningful. The important part in that sentence is: under actual working conditions. Working condition is interpreted here as conducting the test with the type of originals that will be used, line and halftone. It serves no purpose to test with continuous tone test strips, other than establishing the basic exposure time, using the strip in the center of the frame. The new microline targets are the best way, dot or line patterns do fine also. Here is why:

Flying across a vineyard in Fresno was an experience for me. Approaching it, I noticed a green field, 100% green. Coming closer, it opened up and the green became interspersed with brown lines, the ground between vines. Looking down onto the field from straight above, only less than 20% of green remained until we looked back from far away. Here it was again, 100% green. A similar observation can be made with a continuous tone test strip. It does have an emulsion that consists of three dimensional silver modules. From a perpendicular view, it has a predetermined density. Turning the strip from the perpendicular, the angle of view becomes oblique and the density increases until it becomes almost infinite near the end.

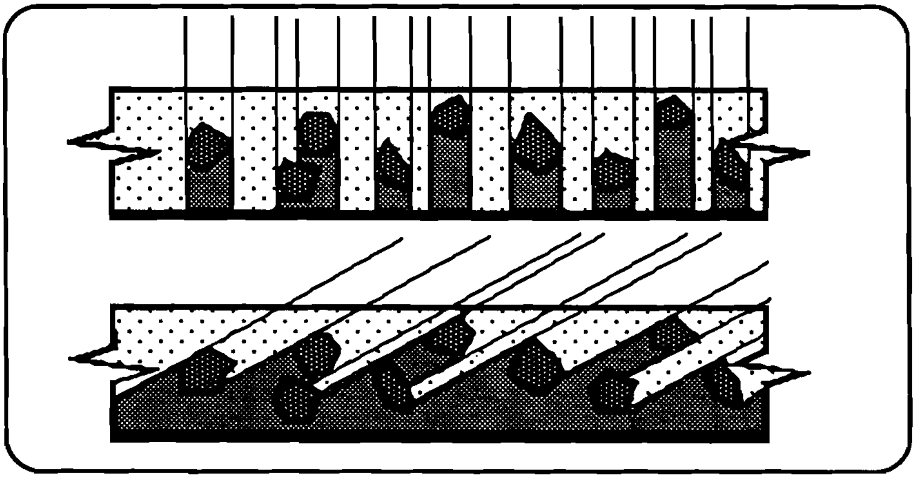


Illustration # 20 - Continuous Tone Test Strip

The change in density with the angle of impact of the light is not a constant function. It varies with the type of material used to produce the test strip. It makes no sense to test for evenness with a device that changes density of its own at different angles. Tests should be made with the same original that will be exposed on a day to day basis: line or halftone. They should be compared with others made on existing or competitive equipment under the same conditions. To specify, the term "same condition": equipment should be tested according to manufacturer's specification. It sounds so logical to reasonable people, yet time and again this is ignored. Lights designed with a wide angle reflector should be used much closer to the exposing surface than narrow angle units. Testing all lights at the identical distance is most unscientific, and unless there is a specific purpose for doing it, will be of little use in the comparative evaluation of lighting equipment.

G. 1b. Measurements.

Using light meters on a frame is a very difficult process that few understand. Light meters by and large are not made to accurately read intensity at an angle to the light. Often the sensor is mounted in a cavity or equipped with an optical system. In those cases the light may not reach the sensor in the same proportion from the side as it will from a perpendicular direction. To test a meter for suitability it should be set up under a light in the center of the frame. After an accurate reading is obtained, it should be tilted at a precise angle and further readings taken. Those readings should diminish according to the cosine law explained above, (D.8). The photocell should then be placed into a corner and turned on the spot. If all readings taken are identical, the meter may be suitable for evaluations. Consideration should be given to the possible changes in light output during the time the measurements are made.

In the OLEC testing lab, a test unit has been developed that takes sample light measurements at designated intervals over the total frame area. To avoid errors due to changes in light output during the total measuring cycle, a control photocell monitors the energy level emitted from a fixed position. Only the difference in intensity is recorded. The test unit is our Robot, "Robert." All readings are recorded on a computer and can be displayed in the form of a "light mountain" that may be turned and inspected from different angles. It can also be displayed in terms of "Isolumes," a line connecting all points of equal intensity. I believe that this word has been coined by Bert Ohlig, V.P. Engineering at OLEC. We have been unable to find any reference of this word.

G. 2. Spectral Radiation.

Halide lamps are designed to emit lines in the blue, violet and "UV A" region that should match the sensitivity of the material to be exposed. There are two parameters in such a matchmaking: one is the sensitivity of the material, the other the emission of the lamp. It is difficult to obtain accurate technical information from many manufacturers of sensitized materials. Sometimes such exact data, as precise spectral sensitivity, is not available. There are good reasons for this: much of the information is gained through extrapolation, relying on soft input (see next paragraph on lamps); sometimes manufacturers do not consider it wise to reveal such data as processes, and sensitivities may change during the life of the product. Even one manufacturer's product can vary so much that it would be most unwise to acquire expensive equipment to match sensitivity with precision. It may quickly be obsolete. Light manufacturers try to cover a reasonably wide range of the spectrum to avoid obsolescence and financial setbacks to the user.

Halide lamps are most difficult to manufacture, hence the price. One of the major problems is contamination. All processes, such as measuring the additives and filling the lamp, are made in a pure Argon environment. The minute quantities of additives, of the highest purity, must be weighed and filled by hand into a tiny spout in the bulb. The most miniscule error or variation may cause significant changes in spectral output or lamp life.

Regrettably Halide lamps are not as consistent as the light manufacturers would like them to be. OLEC has concentrated on a dual spectrum type, the L 1250, (Illustration: #17) made by Philips under tightly controlled conditions. It has proven to be one of the most stable and consistent lamps.

Making tests with a specific lamp, of any manufacture, may not be significant in an absolute sense. It could well be that the performance will deteriorate rapidly, as it does with overdoped units. The next lamp of the same type may produce a different result in total power as well as in spectral output.

G. 3. Continuous and Pulsed Radiation.

Emulsions are sensitive to electromagnetic radiation, light and UV. Such sensitivity may change with the difference from pulsed to continuous radiation. The human eye can perceive a flash of incredibly short duration, simply because the image is retained for a while until the nerves and brain cells have completed their work. For this reason a flashing light with high intensity pulses will appear to be much brighter than a continuous light of the same integrated power radiation.

Photosensitive surfaces, especially photopolymers, have very specific personalities too. Some can react fast and decay just as fast, true integrators of light energy; some act just as the eye with quick response but slow decay, ideally suited to get extra power out of pulsing lights; some are slow to react, so slow that short pulses pass them by before they wake up. The last type of product should be recommended for use with continuous lights only. Halide lamps are pulsing lights, to some extent.

G. 4. Effect of Light Intensity.

Many of the slower acting half-tone materials do not feature a straight Gamma and often have a high threshold/toe value. That means with higher intensity and shorter exposure times the contrast and apparent sharpness of the result can be increased. Greater definition is not always the goal in reproduction, but this method can be used as a tool when needed. It works better on some films than others. With modern electronic light integrators and shutters that act fast and cover evenly, there is no longer any reason to stay with exposures of 10, 15 or 20 seconds "to control the light." Such phrases date back to the era of kitchen timers. Every time I prove the consistency and quality of result to dealers or manufacturers with exposure times well under 10 seconds, I am told that customers, users, will never accept such methods. Whenever I present it to customers they will never go back to long exposures. Who is kidding whom? So much for progress.

H. Other Contact Lights.

The lights as described above are most commonly used in the trade in the US today. There are also some high power pulsed Xenon lights still being operated, performing well in a few applications. New ones are rarely added. They are very expensive and do not peak in the spectral area demanded in the Graphic Arts. Much of the spectral radiation is in the visible range, that is not used on half-tone materials, and effectively goes to waste. Xenon lights have a relatively high IR content.

Water cooled super high pressure mercury lights appear on the market from time to time. That kind of source is much older than any light unit covered in this paper, other than fluorescents. These lights have an almost continuous spectrum through the visible. Little of the real energy is converted into a useful exposure light. The other reason for its rejection is the high cost of upkeep and its complexity. The lamps deteriorate in light output and have a shorter life than other lights. Water cooling has numerous drawbacks.

I. New Developments.

Lately there has been talk about the new Microwave lights. These light units have been used in curing for some time. Recently small round lamps with additives have been developed that fit precisely into some of the spectral windows used in the exposure of contact materials. The most surprising aspect about these lamps is the lack of any electrode or other metal part within the lamp. They just look like a glass golf ball, in the 1500 Watt size. Without the electrodes, many limitations in the use of spectral additives have been removed, and we expect that new lamps of this type will feature spectral lines more precisely patterned towards UV and violet sensitive materials.

These lights feature a very quick start, about 3 to 5 seconds to reasonable stability, and seem fairly repeatable, much more so than the so called "instant starts." The light I observed did not have the ability to quickly restrike with an interval of about 20 seconds to the next exposure. At this time this type of system is still very expensive with user prices around $6,000 for a 1500 Watt unit. We will be watching the developments and are sure you will too.

Numerous improvements to existing lights are on the drawing boards at OLEC and will add to the usefulness and automation of our trade. They include programming units for dry dot etching, automated filter slides for point sources and large printing lights. Two items are on the back burner, waiting for demand to develop: voltage regulation of high precision for resistive loads and compact, collimated lights with small light emitting areas.

J. Postscript.

I hope that this paper will contribute to the understanding of lighting used in the Graphic Arts. I hope that it will initiate discussion and entice experts to contribute more specialized papers on some of the subject matters raised. I hope that it will assist students in their quest to succeed and will give them encouragement to enter into the field with new ideas and enthusiasm. I hope that it will benefit our great communications industry worldwide.

K. Acknowledgements.

American Conference of Governmental Hygienists: Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment

General Electric Company, Nela Park, Ohio: General Information Publication

Illuminating Engineering Society, New York: Lighting Handbook

Lewis R. Koller: Ultra Violet Radiation, Second Edition

U S Department of Labor: OSHA General Industry Handbook, Edition 3-11-83

Van Nostrand / Reinhold: Scientific Encyclopedia, Fifth Edition