Heat Damage To Prints: Part I

New theater construction emphasizes "wall to wall" images on screens that often exceed fifty feet in width. Only five years ago, the average xenon bulb power was 2000 watts. Today, power levels of 4000 watts are common, with some theaters using as many as 7000 watts to project 3' mm film onto 80 foot screens. Focusing all that power through a postage-stamp size piece of film can cause problems ranging from image flutter and focus drift to permanent print damage like blistering, scorching, fading and dye migration. In our years of studying the effects of excessive heat on film, Kodak has identified three major areas of concern: improper or non- existent use of heat filters, excessive bulb current, and maladjustment of bulb focus causing a "hot spot."

Heat Filters

Use of efficient heat filters is recommended for all projectors and is mandatory for any lamp larger than 2000 watts. Aluminized, silver, or rhodium surfaced reflectors without heat filtration are intended only for specialized applications and should not be used for theaters. Xenon bulbs emit a large amount of their energy in the infrared portion of the spectrum. Excess infrared energy absorbed by the film is a major source of heat damage, especially with black-and-white prints (silver grains absorb more infrared energy than color dyes).

An efficient heat filter removes most of the damaging infrared energy produced by the lamp. Most heat filters rely on diachronic coatings on the reflector, making it reflect visible light and absorb infrared energy. Consoles with vertically-mounted bulbs usually use a flat diachronic mirror set at a 45-degree angle, which reflects visible light to the aperture and transmits the unwanted infrared energy to a heat sink.

The efficiency of heat filters varies among manufacturers, and is affected by the age and condition of the dichroic coatings. When purchasing new lamphouses, compare the efficiency of the heat filter system in rejecting unwanted ultraviolet and infrared energy. Always keep the surface of the mirror and heat filters clean and dust free, using the cleaning procedures recommended by the manufacturer. Dichroic coatings are very fragile and easily damaged if cleaned improperly. Heat filters with obviously worn, pitted, or damaged dichroic coatings should be replaced. Do not remove heat filters or use reflectors with no heat protection, even to get a bit more light on the screen. You'll get a bit more light-and a lot more heat damage

Bulb Power

The wattage of the xenon bulb has an obvious correlation with the available light output and the potential for heat damage. Although film damage was possible with a 2000-watt bulb, it usually was associated with insufficient heat filtration and gross misalignment of the lamp focus, causing a "hot spot." With bulbs over 4000 watts, film damage is likely to occur with any misalignment of the lamp focus or with poor heat filtration. Running a lamp higher than its rated current range will greatly reduce bulb life, risk catastrophic failure (explosion), void the warranty, and increase the amount of heat. The slight increase in light is not worth it. A good practice is to set up a new bulb to produce the desired screen luminance and uniformity at slightly less than the rated current, and then increase bulb current as the bulb ages and becomes less efficient. DO NOT EXCEED THE MAXIMUM RATED CURRENT.

Illumination Uniformity

Alignment and focus of the lamp are important to achieve good uniformity of illumination on the screen and avoid "hot spot" damage to the film. Focusing the lamp to achieve a bright spot at the center of the screen, with significant fall-off at the sides and edges, not only produces a non-uniform picture but also concentrates the energy of the lamp on a small portion of the film, greatly increasing the risk of heat damage.

Carefully align the lamphouse following the manufacturer's instructions. Alignment tools usually use special jigs and a string or laser to assure optical alignment of the bulb, reflector, aperture and projector lens. The distance between the reflector and film aperture should be set to the exact specification. After the bulb is installed, position and focus should be set to achieve symmetrical distribution of the light and uniform illumination of the film aperture. In no instance should the bulb focus be set to deliberately produce a "hot spot," resulting in less than 75% screen luminance uniformity. Bulb position and focus should be checked periodically and each time the bulb is rotated or replaced. If you lack either training or tools, leave the job to a qualified service technician.

Other Factors

Theaters using large lamps should consider additional equipment that will improve the quality of the screen image. Curved film gates gently curve the film, making it more rigid, reducing focus flutter and improving focus uniformity across the image. Air pressure stabilizers (e.g., Century Cine-Focus) claim to improve focus stability. High-pressure air jets have sometimes been used to cool the film. Water-cooled gates keep the film trap rails and aperture cooler, increasing operator comfort (no burned fingers during threading), and minimizing heat-induced frictional changes that could cause unsteadiness and increase film wear. We have seen rare occasions where film damage occurred when the film contacted very hot metal components in the gate. Some lamphouses (e.g., Christie "Reference" Console) have automatic lamp focus that redistributes the focus pattern to optimize illumination of flat and scope apertures.

See Part 2 of "Heat Damage To Prints"

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Heat Damage To Prints: Part 2

We will consider the effects of radiant energy on film, heat damage, and how to determine whether you have a heat and problem and how to fix it.

Effect Of Radiant Energy

During projection, the film absorbs radiant energy. This energy causes a very rapid increase in the temperature of the thin emulsion layers when it is absorbed by the dyes or silver grains in the emulsion. The transparent film base absorbs a relatively small portion of the energy so it doesn't heat as quickly. The heat causes the emulsion to expand, displacing the center of the film frame away from the projection lens, which is called "negative drift."

As the radiant energy increases, the drift may vary from frame to frame. When the variation exceeds the depth of focus of the lens, the screen image loses sharpness (focus "flutter"). This is particularly apparent with the use of short focal length lenses. At even higher energy levels, moisture is driven out of the emulsion, causing it to shrink and the center of the frame to move toward the lens ("positive drift"). When some frames drift toward the lens and others drift away, the depth of focus is greatly exceeded, causing focus shifts. Film in this condition is nearly impossible to focus.

These focus effects depend upon several factors:

1. The moisture content of the film is influenced by how it was dried after processing, the drying effect of multiple projections, and the relative humidity in the booth. Kodak recommends maintaining a relative humidity of 50 to 60 percent in the booth.
2. The "core set" (winding) of the film is very important. Based upon Kodak studies, SMPTE Recommended Practice RP 39 calls for maintaining an emulsion-in winding to minimize focus drift problems. "Core set" is also influenced by the diameter of the core of the reel on which the film is wound. Film should always be wound on cores or reels with the largest practical hub diameter. This is why trailers wound on tiny cores often have severe focus flutter.
3. The design of the film gate (curved or straight) and the gate tension are important factors.
4. The density (darkness) of the film image contributes to the amount of energy absorbed by the film, with dark scenes showing more flutter than light ones. This is the reason flutter is often more visible in the closing credits (white letters against a black background).
5. The amount of energy going through the film frame is the single strongest determinant of a stable image

Heat Damage

Excessive radiant energy can cause permanent damage to the print. Because silver grains absorb more infrared energy than dye images, black and white prints are especially sensitive to improper heat filtration. "Blistering" occurs when the energy level is so high that the emulsion heats to the point of bubbling away from the base. In extreme cases, the film actually chars.

With color prints, excessive radiant energy can cause the emulsion to heat to the point of the layers separating internally. This "emulsion void" first manifests itself onscreen as a frost-like crystalline (snowflake) pattern in darker areas of the scene. This is caused by the refraction of light at the internal separation. Looking at the print film itself, reflected light usually reveals opalescent spots in each frame, corresponding to the "hot spot" of the projector. Viewed from the emulsion side, these spots are often magenta or blue. Viewed from the base side, the spots are green or yellow. This is due to the void that occurs within the emulsion layers. The magenta layer is on top, cyan in the middle, and yellow at the base. Depending upon the film type and power level, this damage may occur within a few times of being projected.

"Dye migration" is another form of heat damage sometimes associated with emulsion voids. Multiple projections with excessive radiant energy can cause the dyes to spread out and move to adjacent areas of the image, causing colored fringes or halos around darker objects or people in the scene. Although current Kodak film stocks are resistant to "dye migration," theatres must maintain their vigilance to prevent heat problems. Certain features may be more sensitive to heat since silver is deliberately left in certain color prints when the cinematographer wishes to increase contrast and shadow density. This is a creative decision which can enhance the appearance of the film, but it can have an adverse effect on projection because of the added density and infrared absorption from the silver left in the print.

Do I Have A Heat Problem?

Good projectionists should watch for signs of heat problems. If obvious damage such as blistering, emulsion voids, or dye migration occurs, the cause must be diagnosed immediately. The first three questions to ask when troubleshooting a heat problem should be:

A. Is efficient heat filtration in place.
B. Is the lamp operating at the proper current.
C. Is the lamp focus adjusted to produce good uniformity without a hot spot.

If a projector causes heat damage despite being properly aligned, contact your theatre equipment dealer, the manufacturer, or a service engineer to explore more efficient heat filtration, the installation of a higher-gain screen, screen curvature, or other ways of optimizing screen light without film damage. Because heat-related damage often takes a few weeks to occur, make it a practice to carefully examine the print later in the run, logging and reporting any damage. Heat damage usually happens in the dark scenes first, since they absorb the most radiant energy. Dye fading caused by excessive ultraviolet energy usually results in the color balance of the print becoming more green, with the highlights turning slightly yellow, especially in the "hot spot" of the projector. If visible dye fading happens during the run, additional ultraviolet filtration may be needed between the lamphouse and aperture.

Addressing Heat-Related Focus Problems

Even if it doesn't produce film damage, high levels of radiant energy can still hurt image quality and audience satisfaction. Fuzzy pictures and poor focus uniformity are especially distracting on big screens where the high power levels and short focal length lenses needed to fill those screens often cause problems. Equipment selection (heat filtration, curved gates, focus stabilizers, modern lenses) play major roles in achieving sharp images on big screens. Don't forget the other factors that can be used to improve focus stability: relative humidity between 50 and 60 percent, emulsion-in winding, gate tension adjustment, and avoidance of small-hub reels and cores.

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