Projection Screen Material Report

AccuCal AV℠

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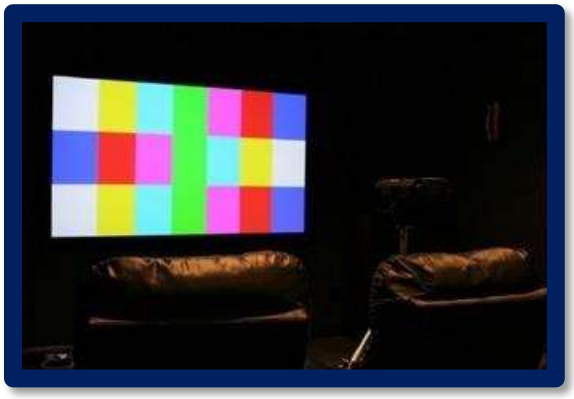
Summary



This report is meant to be an aid for selecting the best front projection screen material for your home theater. It includes measurements of screen gain, color shift and sound loss for acoustically transparent products. It also includes my observations of how these materials look in a reference theater environment. Some of these materials are not available for retractable applications and the quality of the mounting system along with masking systems are outside of the scope of this document. **You should always get a sample of the material you plan to use and compare it to a sample of the best in class material in your theater if possible to be sure it meets your expectations. These materials under normal room lighting do not always appear the same as they do when used as a screen material.**

The report includes no pricing information because it is too fluid and many options can be added that dramatically alter the cost. I highly recommend getting estimates of cost for materials you find promising as these products can vary in cost. A recommended moderate or high gain screen can be significantly more expensive than some of the recommended low gain products.

There is also guidance on selecting the right screen material for your room and how you can achieve the sharpest image from your system.

The primary reason I prepared this report is because many vendors misrepresent the gain of their materials. It is such a common practice Seymour AV includes gains that they call benchmarked which are relative to competitors and unbenchmarked which are what they measured relative to a standard. I have encountered so many home theaters that are incapable of achieving even 9 fL from the screen with a new lamp that I cannot count them. This situation is improving in the last several years because the light output of many projectors has increased by a factor of two, but many people want the biggest screen they can possibly fit in their room. It is important to use actual screen gains and design your theater so it has the proper light output for your environment.

The findings in this report are based on some of the best instruments available including a $24,000 Photo Research PR-670 reference spectrophotometer and a $1,300 ACO Pacific Type 1 microphone. I also have extensive experience with over 2,000 home theaters, several professional post production theaters and I also own one that I use about 1,000 hours a year.

I would be interested in samples of materials that people are using that are not in this report if you found them to be of high quality.

Contents

Selecting a Screen

The most important thing to remember in a home theater is that the projector, room, lighting and screen perform as a system. You should not select one without knowing the other.

The key things to consider in selecting a screen are:

- Aspect Ratio
- Viewing angle
- Gain
- Fixed or retractable
- Masking system
- Acoustically transparent or not
- Boarder type
- Room light level

Deciding on a screen is an iterative process between screen properties, screen features, projector cost, projector light output, room furnishing, screen cost, seating location and the location of the projector. Projector and screen manufacturers also complicate this by frequently overstating what their products are capable of.

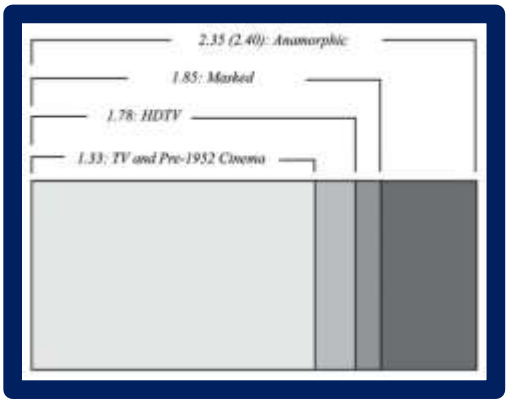
Actual projector light output (lumens), screen surface area and the installed screen gain will determine how bright the image is. The desired light output from the screen will vary based on the application. The lowest light level I would target is 9 foot Lamberts if you must push the limit with screen size. For a typical system I would target between 14 and 18 fL as the starting light output from the screen. This will allow for some light loss with time for the product which can be very substantial. The lower the initial light level the shorter the usable lamp life will be. If the projection application is for a room with normal light levels like a bar I would target 30 to 50 fL. Any room that is illuminated to a significant level will reduce the quality of the image dramatically. Some screen materials can help with ambient light, but nothing is better than a dark room with dark furnishings.

There is a common perception that the darker my room is the dimmer I can run the image. That perception is false. For a completely dark room around 12 to 15 fL maximum will give the average person the best image for film reproduction. At normal light levels the human eye operates in the photopic region where we see color normally. When things are very dark the eye cannot see color and operates in scotopic vision. Between photopic and scotopic we are in mesopic vision where we do not see color as well as photopic, but not yet colorless. With a maximum light level around 15 fL images will look bright and vivid in a dark room like they are supposed to. When you drop down below 12 fL maximum from the screen I find things start looking less colorful. In a dark room above 18 fL the light from the screen can start being fatiguing. I have been in many theaters where the projector was insufficient and operated from

3 to 6 fL. These theaters fall far short of those with 12 to 15 fL no matter what the surroundings are. The smaller the screen the brighter it can be in a dark room without being annoying.

Projector lumens are a huge factor in the process of screen selection. When you are comparing projectors be sure to find out how many lumens are actually being achieved for that unit in a color accurate mode. This is frequently as little as half or even less of what is advertised. Some projectors offer manual irises which can be very useful in adjusting the light output to match the screen. Lamp power adjustments can also be available. High lamp mode can be a problem with noise level if the machine is mounted close to the seating area. High lamp mode will also shorten the lamp life by as much as 50 percent. The lumens available will also depend on the relative lens zoom used. The closer you are to the maximum throw ratio for a projector's lens (further from the screen) the lower the light output. This can lower the light output another 25 percent. 3D glasses typically reduce the light output by about 80% and should be considered in the design if high quality 3D images are desired.

The first decision to make on the screen is will it be fixed or retractable. The room will frequently determine this, but you should be aware of the consequences involved with this decision. Retractable screens have more problems with ringing with the sound system, mechanical failures, wrinkles, bugs getting squashed on the screen, deformation of the projection surface and black edging that does not hide the light spill. The edges of retractable screens are not usually as straight as fixed ones resulting in the image not properly fitting into the projection area. Some retractable screens use wire tensioners to help remove wrinkles and keep the screen straigher. Others also use heavy bars at the bottom to help keep them flat. The larger a retractable screen is the harder it is to keep flat. It is very rare for a screen to perfectly match the image size from a projector. Because of this some light (1 to 3 percent of the image) will either spill onto the black edge or the image will have a gap between the black edge and the projection surface. Many fixed screens use a velvet material that will hide these errors very well if you spill a little of the image on to the frame. Zero edge fixed screens are becoming popular as well and have similar problems as retractable screens with lining up the image well on the screen.



A projection system does not have to match the 1.78 aspect ratio of your standard 16x9 HDTV. A 2.35 screen is a popular screen size for a person who watches a lot of movies since about 50% of movies are released in this aspect ratio. Most other movies today are 1.85. People using a 2.35 screen commonly have an anamorphic lens or a projector with lens memory that will fit the image to the screen and eliminate the black bars. Masking systems are also common to eliminate black bars for sources that do not fit your screens aspect ratio.

The size of the screen is usually based on a target viewing angle, room size and the number of seats you want to accommodate. THX recommends a 36 degree horizontal viewing angle for a 16:9 screen. If you are installing a 2:35 aspect ratio screen a 45 degree horizontal viewing angle is recommended. This is the same as you will find 2/3 of the way back from a quality commercial theatrical screen showing a 2:35 movie. The closer you sit the smaller the surface area can be keeping the viewing angle the same and the more likely it is a lower cost projector and screen will work well with your screen choice.

Actual screen gain is one of the most important factors in screen selection. A value of 1.0 means the screen will reflect all of the light back to the viewer from the projector. A value of 2.0 means that you will see an image twice as bright as a piece of printer paper would look. This happens because the light from a 1.0 gain surface is reflected uniformly while that from a 2.0 screen is reflected more toward the viewer than the sides. This report includes measured values for screen gain with a typical ceiling mounted unit. When a projector is mounted lower the actual gain will be higher in many cases. This is truer for the products in the high gain category than the moderate or low gain. Like projectors the actual screen gain is frequently overstated. There are some negatives to using a screen with gain. These include image artifacts like sparkles and grain, uneven image brightness and color errors. Screen gain also will fall off as you move away from the center of the screen. The wider the seating is compared to the screen width the more difficult it will be to take advantage of screen gain. This effect is also stronger the higher the screen gain is. Screen gain can help with reflections from the side walls, floor and ceiling washing out the image. If you have a room with light colored furnishings a product like a Stewart FireHawk will help reduce these reflections and improve image contrast greatly. Higher gain screens are also easier to damage from cleaning and abrasion because of the complex surface coatings.

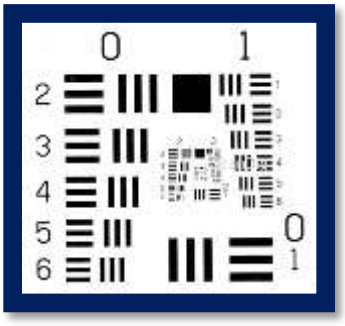
The next decision to make is will the material be acoustically transparent or not. Acoustically transparent surfaces allow you to position the speakers behind the screen. The larger the screen the more difficult it is to locate the front speakers such that they do not obstruct the image and are unobstructed for all of the viewers. This is especially true when multiple rows of seating are used. Generally 2:35 aspect ratio screens over 9 ft in width are where acoustically transparent materials become more important. These materials either have small holes in them or are some type of woven material. The ones with holes are available with higher gain materials and are generally usable at 15 feet or more. The weaves are generally 1.0 gain or less and several are usable at 11 feet or more. Most weaves will impact the sound less than a perforated screen. These materials can also present complex false patterns from interference with the material and the display pixel structure. Some vendors can tilt the product to reduce this problem. Test patterns can be used with screen samples to ensure your system will not have these problems.

Curved screens are an option that is available for 2:35 aspect ratio screens. These can offset some of the distortion from using an anamorphic lens. Curved screens will also reduce the impact of side wall reflections which tend to be more of a problem with 2:35 screens because the proximity of the screen to the sidewalls is closer than most 16:9 systems.

Masking systems can be used to mask off the unused areas of the screen. This helps render the image with crisp dark boarders even when the image aspect ratio does not match the screen. These systems are available motorized in the horizontal and vertical planes. They can also be removable panels to change a 2:35 screen to 16:9.

This calculator from Accupel is a great resource to determine viewing angles, screen luminance and seating height to determine if the front row will obstruct the back row.

How Sharp Is That Screen?



Many screens are advertised today as being compatible with 4K. If you are concerned about having the sharpest looking projected image you need to be concerned about every element in your theater and not just the screen material itself.

An important thing to realize is that one of the primary benefits of 4K is the fact that it reduces the image artifacts and softening caused from digitally sampling the analog world and the subsequent Nyquist filtering requirements. The same thing happens with digital sampling of music. CD's are sampled at 44kHz to be able to allow the filters to pass 20kHz which is the common limit for human hearing. 2160p (4K) has the bandwidth to allow the camera to filter an image properly to get a 1080p image on your screen unadulterated if everything is done properly. This digital sampling problem is the reason that an animated movie from Pixar looks so much sharper on Blu-Ray than the best camera image which must be filtered to avoid horrible artifacts. Many 1080p cameras also have insufficient filtering which results in many image artifacts. Computer animation is not subject to the analog sampling problem and does not need to have sampling rate artifacts at 1080p because the image is actually rendered at 1080p and not sampled from the analog world.

Whether you have 4K or not your projection system's final resolution is going to be determined by the following.

- Image contrast
- Projector performance
- Light output
- Screen Texture
- Screen Artifacts
- Viewing distance

Maintaining image contrast is very important and is the primary way we see details in an image. Ambient light and reflections from the walls can dramatically reduce image contrast. Gain screens can be used to reduce reflections, but gain is not nearly as effective at reducing the impact of ambient light on image contrast. Dark surfaces in the room are the most effective way to maintain image contrast. Surfaces closest to the screen will be dominant in maintaining image contrast. Keeping the screen away from side walls, ceilings and floors also helps. The larger the screen the more difficult this is to do. Using very directional task lighting that does not hit the screen is the best way to have light in a room with a projector and not dramatically reduce the image sharpness.

Image contrast and system resolution is also dictated by the projector type and optics as well. DLP is the best technology if you want to have the most detail out of the projector. Resolution is not just about pixel count. It is also about how high a contrast those pixels are coming out of

the projector. The light path of the imager plays a significant role in this along with electronic filtering algorithms. LCD type products scatter the light internally much more than a DLP reducing contrast making it possible for a 1080p DLP to be sharper than a 4K LCD. 4K sources feeding 4K LCD on the other hand can reduce artifacts even when the product is less sharp making the resulting image smoother.

Our visual acuity is tied to how bright an image is. If you do not have sufficient light output you will have difficulty seeing fine resolution. It is important to have reasonably close to peak visual acuity to appreciate the highest quality images. This corresponds to about 1 fL (Army Research Laboratory ARL-TR-5393, Figure 5) to retain about 80% of your eyes resolving power. Since many images heavily reside in the 30%-50% signal range peak this equates to a minimum peak light output of about 14 fL using a 1 fL limit and the Army research. I personally find images below about 12 fL begin to lose detail at 1080p along with color richness. It therefore is necessary for your system to be reasonably bright to enjoy the benefit of a high resolution projector.

Screen texture can reduce its resolution from interference with the pixels, but it depends on the pixel size relative to the texture. The smaller the pixels on the screen the more likely a texture will interfere with it. Texture is most pronounced with acoustically transparent screens and can be seen as moiré on the screen when the pattern is too larger relative to the pixel size. The larger the screen is the less likely this problem is to be an issue. In general screens over 10 ft wide rarely have moiré from a weave or perforation pattern. The best way to prevent this is to test a sample of the material in your theater with your projector using an image size that is the final size your plan to use along with working with the manufacturer to tilt the pattern to best suit your situation.

Screen artifacts are typically the sparkle and shimmering elements resulting from the presence of coatings that create screen gain. The size of these elements relative to the pixel size will depend on the screen size. If you are sitting more than 14 ft from the screen these are not likely to present much problem with resolution. The screen materials recommend under the low gain section of this report will display the fewest of these and should be strongly considered for the highest resolution applications assuming wall reflections will be minimal. A High Power retroreflector is a gain material that has few artifacts and will retain image resolution, but it needs to be used with care because of its special installation needs.

Viewing distance is an important aspect to seeing detail in an image. There is also a comfort factor with respect to screen size. I find a 36 degree viewing angle for 1.78 aspect ratio to be comfortable and 45 degrees for 2.35 to be comfortable as well. This corresponds to the following:

- 36 degrees - 53 pixels/degree (1080p), 107 pixels/degree (2160p)
- 45 degrees - 43 pixels/degree (1080p), 85 pixels/degree (2160p)

Tests by NHK (ITE Technical Report Vol. 35, No. 16) have shown 310 pixels/degree is needed for an image to reach the limit for human resolution. Needless to say we should be able to benefit

from 4K and even higher resolutions without changing the viewing angles used for comfort reasons. My own observations of 4K displays agree with the test conducted by NHK. It is easy to see the improvement of 4K from distances much greater than one might expect from the simple effect of seeing the pixels themselves. This is likely due to the difficulty of digitally sampling the analog world we live in.

Low Gain Screen Materials

These products are ones that presented very little to no gain in testing even though some claimed to have significant gain. The recommended products are the ones best suited for rooms with dark furnishings, little ambient light and projectors that have enough light output to accommodate the lack of gain. When used in the proper environment the recommended products in this group will give the most artifact free images possible. The gains shown here are for a ceiling mounted unit. A slight increase in gain is possible if the unit is mounted lower.

Material	Published Gain	Measured % Diff	On Axis Gain	Off Axis Gain	On Axis Max. xy	On Axis Avg. xy	Off Axis Max. xy	Off Axis Avg. xy
Snowmatte 100 or StudioTek100	1	2%	1.02	1.00	0.002	0.001	0.003	0.001
Carada Classic Cinema White	1	-3%	0.97	0.95	0.003	0.001	0.003	0.001
Da-Mat®	1	9%	1.09	0.98	0.002	0.001	0.003	0.001
MaxWhite	1.1	-6%	1.03	0.99	0.004	0.002	0.005	0.002
MaxWhite FG	1.1	-5%	1.04	1.02	0.003	0.001	0.004	0.001
CineWhite	1.1	-10%	0.99	0.97	0.004	0.002	0.005	0.002
Cinema Vision	1.3	-20%	1.04	0.95	0.008	0.003	0.010	0.004
S-AV Glacier White	1.1	-5%	1.05	1.02	0.004	0.002	0.004	0.002
SolidPix1 Matte White	1	4%	1.04	1.02	0.007	0.002	0.007	0.002
Brilliant White	1.4	-27%	1.03	1.01	0.006	0.002	0.006	0.003

Green – Best in class
Bold – Recommended

SnoMatte 100 (StudioTek 100) - This material was very color neutral. It appeared to have a very smooth surface. It had no surface sheen or sparkling elements. This material is exceptional at extreme viewing angles and is used in some of the world's leading post production facilities due to its stellar performance. This is the best material tested for a neutral screen material.

Classic Cinema White - This material was very color neutral. It does have a slight amount of texture, but this was not visible at a 9' viewing distance. It did not appear to lend much character to the image which is a good thing. It has a very slight sheen compared to a piece of paper, but I did not notice it in real images. This is the closest alternative to SnoMatte 100. **Update- Reformulated version being sold now is not recommended. It is has sparkling elements and is not uniform.**

Da-Mat® - This material was very color neutral. It does have a little more texture than the Classic Cinema White, but this was not visible at a 9' viewing distance. It had a slight sheen to it which was visible on images infrequently.

MaxWhite & MaxWhite FG- These materials were very color neutral. It does have a some texture. This was slightly visible at a 9 foot viewing distance. This material also has some sheen that is visible on bright images.

CineWhite - This material was reasonably color neutral. It does have a slight amount of texture, but this was not visible at a 9 foot viewing distance. It did not appear to lend much character to the image which is a good thing. This material also has some slight sheen, but I did not notice it on images.

Cinema Vision - This material is not as color neutral as one would like. It does have a slight amount of texture, but this was not visible at a 9' viewing distance. The color shifts induced by this material were strong enough to bother some people. This material did add character to the image that was distracting compared to the other samples. The sheen on this product was visible on brighter images. The gain of this material was not high enough to justify its use. The negatives of this product did not offset its positive attributes and is not one I would recommend.

S-AV Glacier White - This material was color neutral. It does have a little more texture than the Classic Cinema White, but this was not visible at a 9' viewing distance. It had too strong of artifacts on brighter image elements to be recommended.

SolidPix1 Matte White - This material was not very color neutral. It does have a slight amount of texture, but this was not visible at a 9 foot viewing distance. It had a tiny number of sparkling elements to increase the screen gain. and a slight sheen The shimmering caused by these elements was visible very rarely in brighter elements of images. This is not a material I would recommend because of its lack of color neutrality compared to competitors' products.

Brilliant White - This material was mostly color neutral. It does have a slight amount of texture, but this was not visible at a 9' viewing distance. It has a very slight sheen compared to a piece of paper, but I did not notice it in real images. This is not a material I would recommend because of its lack of color neutrality compared to competitors' products.

Moderate Gain Materials

These products are ones that presented characteristics of moderate levels of gain in testing. Some have screen gain close or less than one because of a gray coating added to reduce the light output of the material. The recommended products are the ones best suited for rooms with lighter furnishings, little ambient light and projectors that might not have enough light output and need a boost in screen gain. The gains shown here are for a ceiling mounted unit. A modest increase in gain is likely if the unit is mounted lower. The visibility of the gain elements mentioned in the comments will decrease with distance from the screen.

Material	Published Gain	Measured % Diff	On Axis Gain	Off Axis Gain	On Axis Max. xy	On Axis Avg. xy	Off Axis Max. xy	Off Axis Avg. xy
StudioTek 130 G3	1.3	-3%	1.27	1.19	0.003	0.001	0.004	0.001
Grayhawk RS G3	0.9	-2%	0.88	0.71	0.002	0.001	0.004	0.002
Neve	1.1	13%	1.25	1.11	0.005	0.002	0.006	0.002
HD Progressive 1.3	1.3	2%	1.32	1.09	0.008	0.003	0.009	0.004
HD Progressive 1.1	1.1	7%	1.18	1.08	0.009	0.004	0.010	0.004
HD Progressive 0.9	0.9	9%	0.98	0.88	0.003	0.001	0.003	0.001
HD Progressive 0.6	0.6	21%	0.72	0.62	0.003	0.001	0.003	0.001
Solar HD	1.3	6%	1.37	1.22	0.004	0.002	0.006	0.003
Wilsonart Designer White	-	-	1.29	1.04	0.002	0.001	0.001	0.001
Video Spectra	1.5	-15%	1.27	1.06	0.003	0.001	0.007	0.002
Pearlescent	1.5	-19%	1.21	0.93	0.005	0.002	0.011	0.004
Tiburon	0.95	15%	1.09	0.87	0.002	0.001	0.002	0.001
Multipix 1.5	1.5	-26%	1.12	1.12	0.002	0.001	0.003	0.001
Multipix 1.3	1.3	-19%	1.05	0.91	0.001	0.000	0.001	0.001
Gamma HD 1.1	1.1	4%	1.14	1.06	0.006	0.003	0.005	0.002

Green – Best in class
Bold – Recommended

StudioTek 130 G3 - This material was very color neutral. It appeared to have a very smooth surface. It had many sparkling elements to increase the screen gain. The shimmering caused by these elements was visible in brighter elements of images. The gain of this material would aid in increasing the image brightness for projectors with lower light output than the screen size desired. Off axis gain was also good. This was the best sample tested of an angular reflective material for increasing screen gain.

GrayHawk RS G3 - This material was very color neutral. It appeared to have a very smooth surface. It also had many sparkling elements to increase the screen gain. The shimmering caused by these elements was visible at moderate light levels with images, but a little less than the FireHawk material. The actual gain of this material was not high enough to offset the light lost by the dark gray tint. This material is intended to aid in rooms with significant scattered light from walls and ceilings. It is a special use material that should be considered with care.

Neve - This material was very color neutral. It appeared to have a very smooth surface. It had few sparkling elements to increase the screen gain. The shimmering caused by these elements was visible in brighter elements of images. The gain of this material would aid in increasing the image brightness for projectors with lower light output than the screen size desired. Off axis gain was also good. This is a good alternative to StudioTek 130 if less gain is needed.

HD Progressive 1.3 - This material was not very color neutral. It appeared to have a very smooth surface. It has few sparkling elements to increase the screen gain. The shimmering caused by these elements was visible in brighter elements of images. The gain of this material would aid in increasing the image brightness for projectors with lower light output than the screen size desired. Off axis gain was also good. This is a good alternative to StudioTek 130 if less gain is needed.

HD Progressive 1.1 - This material was not very color neutral. It appeared to be a very smooth surface. It also has a very slight sheen to it which was visible on images infrequently. It did not add much character to the image. There were a few very bright sparkling elements in this product. This material is designed to aid with rejecting light from reflections and may help in that situation.

HD Progressive 0.9 - This material was very color neutral. It appeared to be a very smooth surface. It also has a very slight sheen to it which was visible on images infrequently. This may explain its gray coloring and yet having a gain very nearly 1.0. It did not add much character to the image. This material is designed to aid with rejecting light from reflections and may help in that situation.

HD Progressive 0.6 - This material was very color neutral. It appeared to be a very smooth surface. It also has a very slight sheen to it which was visible on images infrequently. The sheen on this was stronger than the HD Progressive 0.9 sample. This material would require much more light to illuminate the same screen size than any other sample tested here. A product like this is for special circumstances and would not fit most people's requirements.

Solar HD 1.3 - This material was reasonably color neutral. It appeared to have a very smooth surface. It had many sparkling elements to increase the screen gain. The shimmering caused by these elements was visible in brighter elements of images. The gain of this material would aid in increasing the image brightness for projectors with lower light output than the screen size desired. Off axis gain was also good. This was very similar to StudioTek 130 with higher gain and more shimmering from it. The material was thinner than StudioTek and easier to stretch out of shape.

Wilsonart Designer White - This material was very color neutral. It was also reasonably smooth so that the surface was not an issue at 9 feet. This is a rigid laminate material that is not made specifically for screen material and must be adapted by the consumer for this purpose. Shimmering caused by the surface was visible in brighter elements of images. The gain of this material would aid in increasing the image brightness for projectors with lower light output than the screen size desired. Off axis gain was not as good as the StudioTek 130 which does resemble

this material. This is a very good angular reflective material for increasing screen gain. Catalog Number D354-60-107

Tiburon - This material was very color neutral. It appeared to have a very smooth surface. It had some sparkling elements to increase the screen gain. The shimmering caused by these elements was very visible in brighter elements of images. This material would aid in increasing the image brightness for projectors with lower light output than the screen size desired. Off axis gain was also good. This product is not recommended because of the very strong sheen. The gain seemed to be too sensitive to head position.

Video Spectra 1.5 - This material was mostly color neutral. The surface was patterned on this product. The color shifts induced by this material would not be strong enough to bother most people. This material did add character to the image that was very distracting compared to the other samples. The sheen on this product was obvious on brighter images. The gain of this material would aid in increasing the image brightness for projectors with lower light output than the screen size desired. This was the most objectionable material of those tested for home theater use and is not one I would recommend.

Pearlescent - This material added a strong color to the images. It appeared to have a smooth surface. The shimmer caused by the screen gain was visible in brighter elements of images. The gain of this material would aid in increasing the image brightness for projectors with lower light output than the screen size desired. Off axis gain was not good. This is not a material I would recommend because of the strong color effect of this material, poor off axis gain and the image quality degradation form reflective elements.

MultiPix Ultra-contrast White 1.5 - This material was very color neutral. It does have a slight amount of texture, but this was not visible at a 9 foot viewing distance. It had many sparkling elements to increase the screen gain. The shimmering caused by these elements was visible in brighter elements of images. This is not a material I would recommend because of its lack of screen gain compared and image quality degradation from reflective elements.

MulitiPix Ultra-contrast White 1.3 - This material was very color neutral. It does have a slight amount of texture, but this was not visible at a 9 foot viewing distance. It had many sparkling elements to increase the screen gain. The shimmering caused by these elements was visible in brighter elements of images. This is not a material I would recommend because of its lack of screen gain compared to the image quality degradation from reflective elements.

Gamma HD 1.1-This material was reasonably color neutral. It appeared to have a very smooth surface. The shimmering caused by the screen gain was visible in brighter elements of images. Off axis gain was also good. The material was thinner than StudioTek and easier to stretch out of shape. This is not a material I would recommend because of its lack of screen gain compared to the image quality degradation from reflective elements.

High Gain Materials

These products are ones that presented characteristics of high levels of gain in testing. Some have screen gain close or less than one because of a gray coating added to reduce the light output of the material. The recommended products are the ones best suited for rooms with lighter furnishings, little ambient light and projectors that might not have enough light output and need a boost in screen gain. . The gains shown here are for a ceiling mounted unit. A dramatic increase in gain is likely if the unit is mounted lower. The visibility of the gain elements mentioned in the comments will decrease with distance from the screen.

Material	Published Gain	Measured % Diff	On Axis Gain	Off Axis Gain	On Axis Max. xy	On Axis Avg. xy	Off Axis Max. xy	Off Axis Avg. xy
High Power 2.4 (retro)	2.4	-22%	1.88	1.03	0.003	0.001	0.009	0.004
High Power 2.8 (retro)	2.8	-30%	1.82	0.90	0.006	0.002	0.012	0.005
DarkStar (retro)	1.4	-10%	1.26	0.66	0.006	0.002	0.006	0.002
Ambient Visionare 1.3	1.3	6%	1.37	1.11	0.003	0.001	0.003	0.001
CineGray 5D	1.5	-33%	1.00	0.82	0.004	0.002	0.005	0.002
Firehawk G4	1.1	-17%	0.91	0.70	0.006	0.003	0.007	0.003
Firehawk G3	1.25	-28%	0.90	0.75	0.007	0.003	0.008	0.003
Black Diamond 0.8	0.8	-1%	0.79	0.49	0.022	0.008	0.024	0.009
Black Diamond 1.4	1.4	-1%	1.38	0.88	0.012	0.005	0.015	0.005
Silver 5D	2	-2%	1.97	1.53	0.004	0.002	0.004	0.002
Starbright 7.0	7	-59%	2.87	1.95	0.006	0.003	0.005	0.002

Green - Best in class
Bold - Recommended
(retro) – Retroreflective Material (all others are angular reflective)

High Power 2.4- This was color neutral on axis, but that fell off as the angle was increased. It appeared to be a very smooth surface. The color shifts induced by this material may be strong enough to bother some people. There is a slight roughness to the surface of this product. This is a retroreflective material that works best when the projector is mounted near the viewer's head. The ceiling mounting in this theater is more common and shows the reduction in performance from this projector orientation. The gain of this material would aid in increasing the image brightness for projectors with lower light output than the screen size desired. The projector should be mounted around head height for maximum gain. This material is highly recommended if you need a boost in light output and reduction in reflections from walls.

High Power 2.8 - This material is not color neutral. It is a very smooth surface. The color shifts induced by this material may be strong enough to bother some people. This is a retroreflective material that works best when the projector is mounted near the viewer's head. The ceiling mounting in this theater is more common and shows the reduction in performance from this orientation. This product did contain some sparkling elements that are visible when viewed at

closer distances. The gain of this material would aid in increasing the image brightness for projectors with lower light output than the screen size desired.

DarkStar – This material is not very color neutral. It is a very smooth surface. It is a stiff material. The artifacts on the image were not as severe as one would expect for a material with this strong of a gain. I would not recommend this product because of the very limited viewing angle. It lost too much light output as you shifted even one seat to the side of center. The projector should be mounted around head height for maximum gain because this is a retroreflective product.

Ambient Visionare 1.3 - This material was very color neutral. It appeared to have a very smooth surface. It is a very stiff material. It had many sparkling elements to increase the screen gain. The shimmering caused by these elements was visible in brighter elements of images. The gain of this material would aid in increasing the image brightness for projectors with lower light output than the screen size desired. Off axis gain was also good. This is a less aggressive alternative to a Black Diamond. This product is constructed on a harder sheet of plastic than the stretched PVC found with the other products in this group.

CineGray 5D - This material was reasonably color neutral. It appeared to have a very smooth surface. It also had many sparkling elements to increase the screen gain. The shimmering caused by these elements was visible at moderate light levels with images, but less than the FireHawk material. This material is intended to aid in rooms with significant scattered light from walls and ceilings. This as an excellent alternative to a Firehawk. It is a special use material that should be considered with care.

FireHawk G4 - This material is not as color neutral as one would like. It appeared to have a very smooth surface. It also had many sparkling elements to increase the screen gain. The shimmering caused by these elements was visible at moderate light levels with images. The actual gain of this material was not high enough to offset the light lost by the dark gray tint. This material is intended to aid in rooms with significant scattered light from walls and ceilings. It is a special use material that should be considered with care.

FireHawk G3 - This material is not as color neutral as one would like. It appeared to have a very smooth surface. It also had many sparkling elements to increase the screen gain. The shimmering caused by these elements was visible at moderate light levels with images. The actual gain of this material was not high enough to offset the light lost by the dark gray tint. This material is intended to aid in rooms with significant scattered light from walls and ceilings. It is a special use material that should be considered with care.

Black Diamond HD 0.8 - This material added a strong color to images. It appeared to have a very smooth surface. The shimmer caused by the screen gain was visible in brighter elements of images. The gain of this material would aid in increasing the image brightness for projectors with lower light output than the screen size desired. Off axis gain was not good. This is a special material designed for rooms without light control. This is not a material I would recommend

because of the strong color effect of this material, poor off axis gain and the image quality degradation from reflective elements.

Black Diamond HD 1.4 - This material added a strong color to images. It appeared to have a very smooth surface. The shimmer caused by the screen gain was visible in brighter elements of images. The gain of this material would aid in increasing the image brightness for projectors with lower light output than the screen size desired. Off axis gain was not good. This is a special material designed for rooms without light control. This is not a material I would recommend because of the strong color effect of this material, poor off axis gain and the image quality degradation from reflective elements.

Silver 5D - This material was very color neutral for such a high gain screen. It appeared to have a very smooth surface. The shimmer caused by the screen gain was very visible in brighter elements of images. The gain of this material would aid in increasing the image brightness for projectors with lower light output than the screen size desired. Off axis gain was still high. This is not a material I would recommend because of the image quality degradation from reflective elements.

StarBright™ 7 - This material is very color neutral. It is a very smooth surface. This material is more stiff and than others tested. It can be permanently creased very easily. This material did add a strong character to the image that was very distracting compared to the other samples. The sheen on this product was obvious on brighter images. The gain of this material would aid in increasing the image brightness for projectors with lower light output than the screen size desired. This was very objectionable material for home theater use and is not one I would recommend.

Acoustically Transparent Materials

These products are woven or perforated for placing speakers behind the screen. The area behind the screen should be black to prevent light from reflecting back. A black fabric is commonly used for this with woven a product that adds 1db on top of the loss shown. The recommended products are the ones that exhibited substantially better performance. It should be noted many of the screen materials on the previous pages are available in a perforated version from manufacturers like Stewart Filmscreen. These micro perforated products will have acoustical properties similar to the Audio Vision product below, but offer the option of substantial screen gain which can be very beneficial. The gains shown here are for a ceiling mounted unit. A slight increase in gain is possible if the unit is mounted lower.

Material	Max.db Loss	Published Gain	Measured % Diff	On Axis Gain	Off Axis Gain	On Axis Max. xy	On Axis Avg. xy	Off Axis Max. xy	Off Axis Avg. xy
Center Stage XD	2	1.2	-21%	0.94	0.93	0.004	0.001	0.004	0.002
Enlightor 4K	2.5	0.98	-14%	0.84	0.83	0.004	0.002	0.005	0.002
Center Stage UF	2	0.8	0%	0.80	0.79	0.003	0.001	0.003	0.001
ClearPix2 White	1	1	-10%	0.90	0.88	0.004	0.001	0.004	0.001
ClearPix3 White	7	1	-8%	0.92	0.91	0.003	0.001	0.003	0.001
SW4500	4	-	-	0.98	0.96	0.004	0.002	0.005	0.002
Falcon	4	1.1	-9%	1.00	0.94	0.006	0.002	0.005	0.002
AcousticPro 1080	2	1	-18%	0.82	0.82	0.010	0.005	0.011	0.005
AcousticPro 4K	2	1.1	-36%	0.71	0.69	0.010	0.004	0.012	0.005
Enlightor 1	2	0.95	-9%	0.87	0.85	0.002	0.001	0.002	0.001
Enlightor 1 Silver Back	2	0.95	-7%	0.88	0.86	0.003	0.001	0.003	0.001
Enlightor 3	4	1.1	-28%	0.79	0.74	0.005	0.002	0.004	0.001
CineWeave HD	3	1.16	-28%	0.83	0.84	0.001	0.000	0.001	0.001
Audio Vision	6	1	5%	1.05	0.96	0.002	0.001	0.003	0.001
Gamma Maestro HD	1	1.1	-25%	0.83	0.83	0.005	0.002	0.005	0.003

Green – Best in class
Bold – Recommended

Center Stage XD - This material was mostly color neutral. It does have a strong texture from the weave used to pass the audio through the screen. The weave used with this material is unusually irregular making moiré more uncommon with it. At 9 feet it was slightly visible. This material would be best for eleven foot or greater viewing distance. At eleven feet this material looked very good. Treble was 2 db down at 20 kHz compared to the level at 2 kHz. The black backing added another 1 db loss at 20 kHz. The audio response effect was a relatively smooth loss from 3kHz to 20kHz. This material is recommended from 11 foot and greater viewing distances.

Enlightor 4k - This material is mostly color neutral. It is a very fine weave. It does have a slight texture from the weave used to pass the audio through the screen. At 8 feet it was slightly visible. This material would be best for 9 foot or greater viewing distance. At ten feet this material looked very good. The material does add a slight sheen to the image. Treble was 2.5 db down at 20 kHz compared to the level at 2 kHz. The black backing added another 1 db loss at 20 kHz. The audio response effect was a relatively smooth loss from 3kHz to 20kHz. This material is only recommended from 8 to 9 feet because of light loss and color errors.

Center Stage UF - This material is very color neutral. It is a very fine weave. Very similar to Enlightor 4K, but it has an uneven weave which should reduce the likelihood of moiré even more. It does have a slight texture from the weave used to pass the audio through the screen. At 8 feet it was slightly visible. This material would be best for 9 foot or greater viewing distance. At ten feet this material looked very good. Treble was 2 db down at 20 kHz compared to the level at 2 kHz. The black backing added another 1 db loss at 20 kHz. The audio response effect was a relatively smooth loss from 2kHz to 20kHz. This material is only recommended from 8 to 9 feet because of light loss.

ClearPix2 Matte White -This material was exceptionally color neutral. It does have a strong texture from the weave used to pass the audio through the screen. At 10 feet it was slightly visible. At 11 feet this material looked very good. Treble was 1 db down at 20 kHz compared to the level at 2 kHz. The black backing added another 0.5 db loss at 20 kHz. The audio response effect was a relatively smooth loss from 10kHz to 20kHz. This material is recommended from 11 feet or greater view distances.

ClearPix3 Supreme White -This material was very color neutral. It does have a strong texture from the weave used to pass the audio through the screen. The weave is much tighter than the Center Stage XD material. At 9 feet it was slightly visible. At 10 feet this material looked very good. A few sparkling elements are visible in brighter scenes. Treble was 7db down at 20 kHz compared to the level at 2 kHz. The black backing added another 0.5db loss at 20 kHz. The audio response effect was a relatively smooth loss from 3kHz to 20kHz. This material is recommended for the 9 to 11 foot viewing distances, but the equalization correction for treble is rather large. Some may prefer this material at all distances if visual performance is dominant.

SW-4500 - This material was tinted for a screen material. It does have a strong texture from the weave used to pass the audio through the screen. This material looked very good from about 11 feet out. Treble was 4 db down at 20 kHz compared to the level at 2 kHz. The audio response effect was a relatively smooth loss from 6kHz to 20kHz. This material is made by Phifer and sold as Sheerweave 4500 Chalk color. This material is recommended from 11 feet or greater view distances for the do it yourself person who wants to buy lost cost material and make his own screen.

Falcon - This material was tinted for a screen material. Falcon is very similar to the SW-4500 material and may even be the same thing with the differences being lot variation. Treble was 4db down at 20 kHz compared to the level at 2 kHz. The audio response effect was a relatively smooth loss from 4kHz to 20kHz. Not very competitive with other commercial screen weaves.

AcousticPro1080™ - This material was very tinted for a screen material. It does have a strong texture and a very open weave used to pass audio through the screen. The weave was also streaking the image because of variations in the thread density. The sample provided did not include the black backing that can be purchased with this material so a Seymour backing was used for light measurements and observations. At 9 feet the weave was frequently visible. This material would be best for 17 foot or greater viewing distances. Moiré will be more of an issue with this weave because it is so open as well as the visibility of objects behind the screen if no

backing is used. Treble was 2 db down at 20 kHz compared to the level at 2 kHz. The audio response effect was a relatively smooth loss from 8kHz to 20kHz. This is not a material I would recommend because of its low screen gain, poor color performance and open non-uniform weave.

AcousticPro 4K- This material was very tinted for a screen material. It was a very fine weave. It does have a slight texture from the weave used to pass the audio through the screen. At 8 feet it was slightly visible. This material would be best for 9 foot or greater viewing distance. At ten feet this material looked very good. The material does add a slight sheen to the image. Treble was 2 db down at 20 kHz compared to the level at 2 kHz. The audio response effect was a relatively smooth loss from 2kHz to 20kHz. This material is not recommended because of color errors and light loss compared to other fine weave options.

Enlightor 1 - This material was very color neutral. It does have a strong texture from the weave used to pass the audio through the screen. The material added a slight sheen to the image. It does have a strong texture from the weave used to pass the audio through the screen. At 9 feet it was slightly visible. This material would be best for eleven foot or greater viewing distance. At eleven feet this material looked very good. Treble was 2 db down at 20 kHz compared to the level at 2 kHz. The black backing added another 1 db loss at 20 kHz. The audio response effect was a rela- tively smooth loss from 5kHz to 20kHz. This is not a material I would recommend because of the image patterning and its low screen gain.

Enlightor 1 Silver Back - This material was very color neutral. It does have a strong texture from the weave used to pass the audio through the screen. The material added a slight sheen to the image. This material imprinted obvious patterning on the image visible to about 16 feet. Treble was 2 db down at 20 kHz compared to the level at 2 kHz. The black backing added another 1 db loss at 20 kHz. The audio response effect was a relatively smooth loss from 5kHz to 20kHz. This is not a material I would recommend because of the low screen gain.

Enlightor 3-This material was mostly color neutral. It does have a strong texture from the weave used to pass the audio through the screen. At 9 feet it was slightly visible. This material would be best for eleven foot or greater viewing distance. At eleven feet this material looked very good. The material used added a slight sheen to the image as well. Treble was 4 db down at 20 kHz compared to the level at 2 kHz. The black backing added another 1 db loss at 20 kHz. The audio response effect was a relatively smooth loss from 3kHz to 20kHz. This is not a material I would recommend because of its low screen gain.

CiniWeave HD™ - This material was very color neutral. It does have a strong texture from the weave used to pass the audio through the screen. The material added a slight sheen to the image. This material imprinted obvious patterning on the image visible to about 16 feet. Treble was 3 db down at 20 kHz compared to the level at 2 kHz. The black backing added another 1 db loss at 20 kHz. The audio response effect was a relatively smooth loss from 8kHz to 20kHz. This is not a material I would recommend because of the image patterning and low screen gain.

Gamma Maestro HD- This material was very color neutral. It does have a strong texture from the weave used to pass the audio through the screen. This material imprinted obvious patterning on the image visible to about 13 feet. Treble was 1 db down at 20 kHz compared to the level at 2 kHz. The audio response effect was a relatively smooth loss from 2kHz to 20kHz. This is not a material I would recommend because of the low screen gain.

Audio Vision - This material was very color neutral. It does have a little more texture than the Classic Cinema White and an obvious hole pattern. The hole pattern was visible up to 15 feet. It had a slight sheen to it which was visible on images infrequently at 9 feet. Treble was 6db down at 20 kHz compared to the level at 2 kHz. The audio response effect was a relatively smooth loss from 4kHz to 20kHz. This material is not recommended because of the high frequency loss and lack of significant screen gain to offset that loss.

Gamma Maestro HD- This material was very color neutral. It does have a strong texture from the weave used to pass the audio through the screen. This material imprinted obvious patterning on the image visible to about 13 feet. Treble was 1 db down at 20 kHz compared to the level at 2 kHz. The audio response effect was a relatively smooth loss from 2kHz to 20kHz. This is not a material I would recommend because of the low screen gain.

Test Method

On Axis measurements are perpendicular to the screen

Off Axis measurements were taken 18 degrees to the side and 6 degrees down, but are of the same location as the on axis measurement point on the screen

Gain measurement is the average of 10 colors ratio of light at the observer location to light sent to the screen.

Max. x y - Maximum absolute change in CIE color measured as caused by the screen for the 10 colors measured.

Avg x y - Average absolute change in CIE color measured as caused by the screen for the 10 colors measured

This room had no windows, dark walls, equipment rack was in the hall not facing screen and minimal light sources were present in the room. All room lighting was off at the time of the tests. The most significant light source was a PC that was dimmed, in the back of the room and facing the rear of the room. Background light sources with the projector off were measured to add 0.000073 fL to the Carada Classic Cinema White screen. All color and screen luminance measurements were made with the PR-670 carefully positioned and tripod mounted to measure an area that was projected as a target from the projector. This was true for both luminance and illuminance measurements. The same measurement series taken at the beginning of the test was also repeated at the end to help ensure that nothing had drifted significantly.

The Carada Classic Cinema White screen used in these tests is the screen installed in this theater. All other screen materials in these tests were samples only from various manufacturers. Screen gain measurements could be influenced by the screen samples not being tensioned like the Carada. Multiple attempts were made to position the sample to keep the sample flat in the area being measured. All screen samples were taped to the Carada screen for measurement. Only one screen sample was used for each screen material tested. None of the samples appeared to be damaged.

The projector in this case was ceiling mounted in the center of the screen horizontally and vertically above the screen. Maximum vertical shift was used in this product. The projector was also warmed up for 2 hours before color measurements were taken to stabilize the output colors as much as possible. The spot measured was 32.5” lower than the projector’s center of projection. The projector was also on high lamp mode and the image sized for an 86” diagonal 16:9 screen near the minimum throw of the projector. This provided a bright image to maximize the signal to noise ratio of the measurements.

The test patterns used to measure light output and color were all created by an Accupel HDG-4000. The patterns used were window patterns to minimize the scattered light sent to the walls,

floor and ceiling. The colors measured included red, green, blue, yellow, magenta, cyan, desaturated blue, desaturated green, desaturated red and white.

The PR-670 was set to measure a 1 degree field of view and extended range with the smart dark feature off. The PR-670 was AC powered during these tests. Actual screen light levels measured between 0.4 fL and 16.5 fL. At no time did the PR-670 report a value as being out of range. Nominally the light levels ranged between 1 fL and 10 fL The MS-75 lens attachment was used to measure the screen and a CR-670 cosine corrector was used to measure the light from the projector directly.

Screen material observations were made in normal room lighting and with light from the projector. Screen observations included test patterns and a variety of movie material. Observations of movie images were made at 9’ at 18 degrees off center and sitting at the center of the screen with an 86” diagonal image and a maximum light level of 15 fL from the Classic Cinema White screen.

No measurements were attempted to measure hot spotting because these problems can vary with the projector, but screens with more gain tend to have more issues with luminance varying with the location of the image on the screen. Retroreflectors like the High Power tend to have fewer problems with this than other high gain options.

Audio was measured with an ACO Pacific MK224PH Class I microphone and Sencore SP495 preamp at 1/24 octave. The microphone was positioned 24 inches from the tweeter and on axis with it. The screen material was 3 inches from the tweeter. Wideband pink noise was measured with and without the material in the sound path and the difference was taken using TrueRTA. Strong problems with comb filtering were observed when the material was positioned very close to the speaker which is not recommended by the manufacturer. This caused an additional 6db variation from 5 to 20 kHz. A Class 1 microphone was used to reduce the interaction with the room at these frequencies. The background noise was NCB 19.

Manufacturer Contact Information

Carada http://www.carada.com/

Da-Lite http://www.da-lite.com/

Elite Screens http://www.elitescreens.com/

Falcon http://www.falconscreens.com/

Screen Excellence http://www.screenexcellence.com/

Screen Innovations http://www.screeninnovations.com/

Screen Research http://www.screenresearch.com/website/index.php

Seymour AV http://www.seymourav.com/

Stewart Filmscreen http://stewartfilmscreen.com/