High Speed Emulsion Stress Syndrome

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Film House, 424 Adelaide Street East
Authors Meeting, 7:00 A.M., Room 103B
Total presentation time - twenty minutes
Session Chair: Tom Allwood

Thank you, Mr. Chairman

A little over two years ago, many of us who work the field of special effects began to experience disconcerting flickering anomalies in some of the footage we shot. Frequently this flickering was quite subtle, and it was sometimes even possible to dismiss it as projector flicker. However, as the footage was frequently being used to create such effects as split screen composites, projector flicker was quickly ruled out because the effect was compounded in a composite and, to our dismay, revealed the split.

Let's look at a short piece of tape that illustrates the problem:

VISUAL - TAPE: Pillsbury **(Tape - from 8:36 to 9:04, 30 secs.)**

This paper then, will deal with how this problem presented itself and how it was eventually diagnosed and finally corrected.

From the earliest beginnings of the motion picture industry, the actinic sensitivity, or "speed" of photographic emulsions has been an obsession of cinematographers. Some of the more fanatical practitioners have gone to extreme lengths to obtain the images they sought. One such is Stanley Kubrick, who insisted that a candlelight scene in Barry Lyndon should be shot in actual candlight. To achieve this, he had a special Zeis lens modified by Ed DiGiulio at Cinema Products to fit a Mitchell BNC with a stop of F 0.7.

VISUAL - SLIDE: Barry Lyndon 1 .

Please bear with the terrible quality of the slides, but they do give some idea of what Kubrick was trying to achieve.

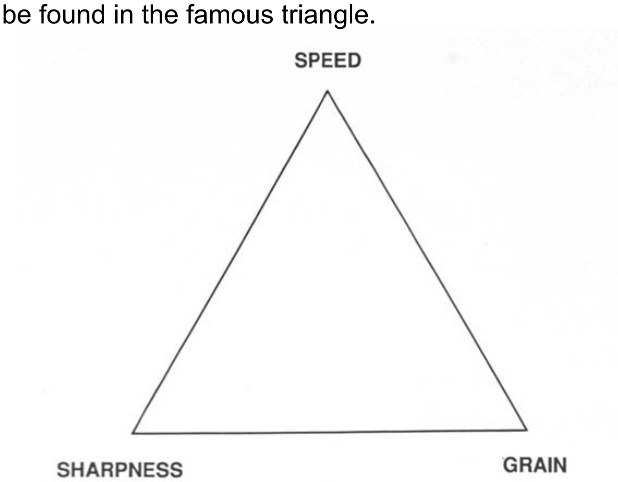
VISUAL - SLIDE: Barry Lyndon 2 .

Other, more recent efforts to obtain great speed have included the use of the 1600 ASA Ektapress 5030, normally a photojournalist filmstock that had to be specially perforated for cine use on the Award-winning documentary Bird Nesters of Thailand.

And, of course, for the ultimate in extremism, there is the work of cinematographers who have borrowed techniques from astrophotographers and "hypersensitized" their film with explosive gases.

All of this only serves to illustrate the pressure filmbuilders have been under to produce ever faster filmstocks. Of, course, it has to be borne in mind there have been some fundamental laws that govern how successful one can be in achieving such a goal.

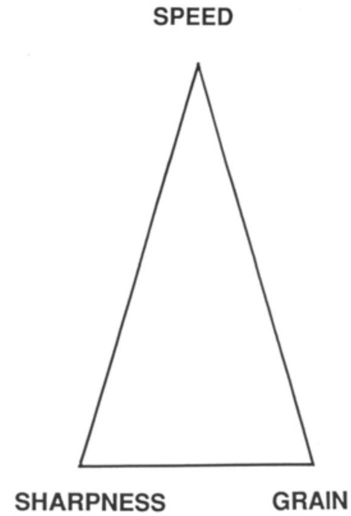
A graphic comprehension of the interrelated nature of the three attributes of photographic film; speed, grain and sharpness can be found in the famous triangle.



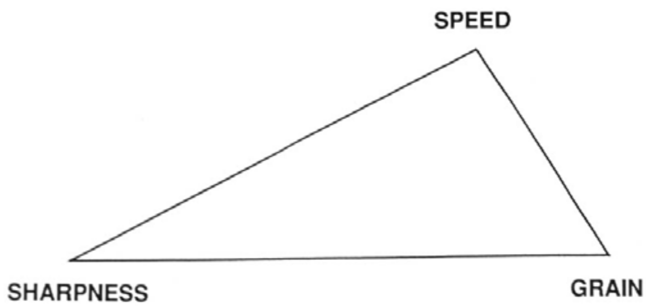
VISUAL - SLIDE: Speed, Grain, Sharpness Triangle - 1 **.**

Here we can readily see that if we want to increase the speed of the film we can do so only at the expense of larger grain and lower sharpness.

VISUAL - SLIDE: Speed, Grain, Sharpness Triangle - 2 **.**



Lowering the grain size produces sharper pictures and slower speed.



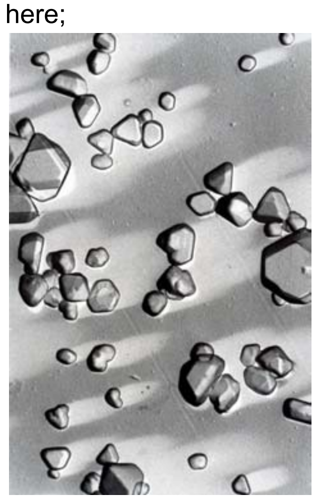
VISUAL - SLIDE: Speed, Grain, Sharpness Triangle - 3 **.**

The bottom line has been that the area of the triangle remains a constant while the shape changes to reflect the changing characteristics. A major advance on this would require that the total area would have to be able to increase.

How to do this? Well, it's obvious that the governing element here is in the crystal itself. And indeed, working at the molecular level of the structure of the crystal has led to the recent breakthroughs in film performance, literally increasing the area of the triangle.

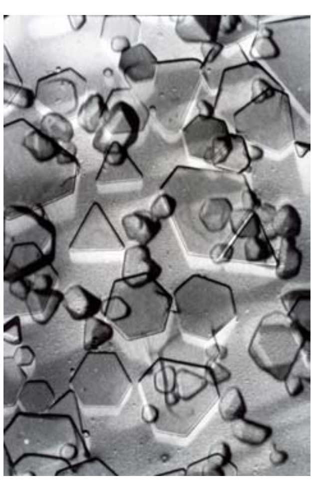
Here is how this was accomplished. The familiar "rock" shaped crystal as seen here;

VISUAL - SLIDE: Conventional Crystal **.**



has been restructured into a tablet or platelet crystal, now known as a Tabular grain, as seen here;

VISUAL - SLIDE: Tabular Grain Crystal.



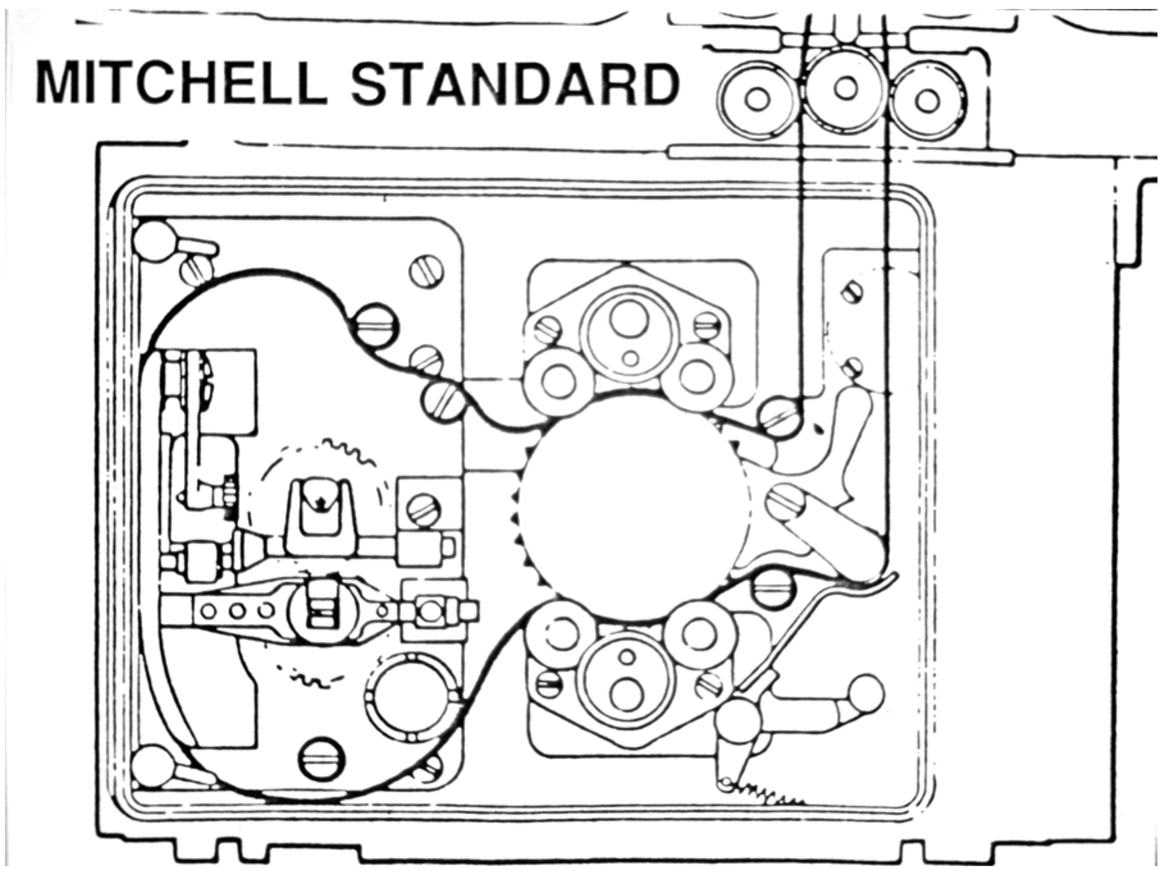
What this new crystal shape does is make it a more efficient target for photons and at the same time provide for a greater packing density of crystals for a given thickness of emulsion. This causes less scattering of light within the emulsion and produces a sharper image. The new tabular grain emulsions also "fill" more effectively, allowing fewer photons to leak through and be wasted, and this property is what enables the emulsion to be faster for the same relative granularity. Thus the triangle is actually made larger.

The effect of this on image quality has been quite tremendous, and we find we have a film that would have made Stanley Kubrick a very happy man back when he was filming "Barry Lyndon." We now have filmstocks reaching speeds of 600 ASA, and the prospect of 1000 ASA in a motion picture filmstock is not out of the question.

However, to return to our dilemma, behind every silver crystal lining there is a cloudy problem. High performance refinements, be they in cars or racehorses, often entail an increase in fragility, and it appears they same may hold true for high performance filmstocks.

The artifacts we saw earlier led to an exhaustive examination of equipment involved in the shoot including tear down of the camera. The optical processes used to produce composites were scrutinised to no avail. The Lab process was suspected and challenged, but could not be demonstrated to be at fault. Eventually the process of elimination led to indications that the problem lay in the filmstock itself.

Examination of black and white separation positives revealed that the phenomena was exhibited chiefly in the Blue record, which is to say the fastest record of the film. Anecdotal evidence narrowed the incidents to those involving Mitchell cameras or those built around the basic Mitchell architecture.

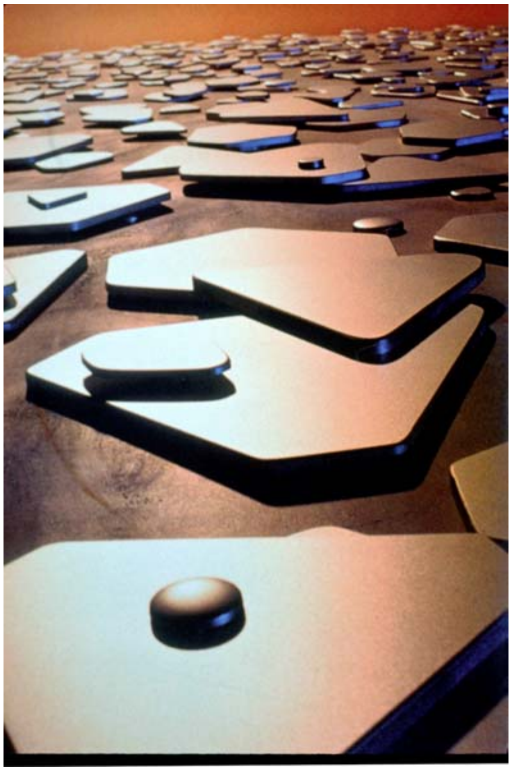


VISUAL - SLIDE: Mitchell Standard film path.

Eventually, the theory surfaced that fluctuations in tension on the film as it negotiated the right angle turn around the "Feed Idler Roller" immediately prior to engaging the drive sprocket were causing localized alterations in sensitivity of the emulsion. And the theory of **High Speed Emulsion Stress Syndrome** was born.

Since not only fast filmstock, but in particular the Blue record (which is to say the fastest record), was susceptible to the effect, attention began to centre on the silver crystals themselves.

VISUAL - SLIDE: Tabular Grain (artist rendering) **.**



A hypothesis developed that the new tabular crystal structures, being relatively very thin, could actually be subject to fracturing and breaking if bent around a tight radius. This concept seemed a little far fetched, but the consequence of such an event would be consistent with the effect, in that the film exhibited a localized desensitization. Consider that if one could actually break one large crystal into two or more smaller ones, one would create a finer grained and slower emulsion, at least where the breakages occurred.

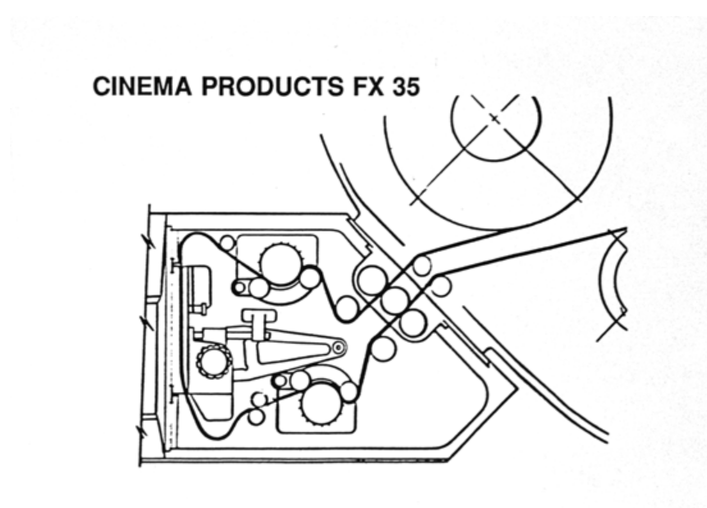
However, this theory was confounded when it became apparent that the desensitization was also transitory. That is, if the stress were applied and the film then allowed to "rest," it would recover its normal sensitivity. The tests at Apogee included both pre-stress tests and post-stress tests, and neither pre or post stress caused the same desensitization effect.

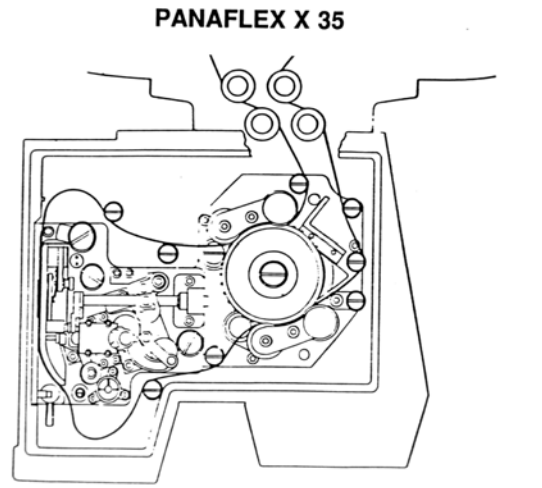
Eventually the hypothesis was modified to satisfactorily account for the transitory nature of the effect. Actual breakage of the crystal probably does not occur. Instead the crystal responds to the applied stress of bending around a tight radius in much the same way that piezoelectric crystals do: it transfers energy—electrons—temporarily. Thus, when the film bearing such crystals arrives at the camera gate for exposure to photons, it is simply not itself. The photons it absorbs under such conditions are unable to change the state of the affected crystals as they would normally and so some crystals remain - unexposed.

Let's look at some examples of various different film threading arrangements for other cameras currently in use. These are illustrations from the American Cinematographers Manual, as well as one for Geoff Williamson's high speed VistaVision camera.

VISUAL - SLIDE:
Film threading - Cinema Products FX 35 **.**

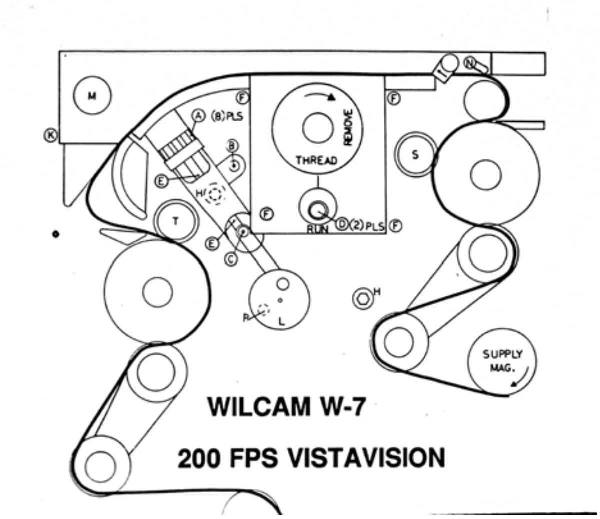
This is the FX 35. The path includes a sharp turn though the radii are fairly generous.





VISUAL - SLIDE:
Film threading - Panavision.

Panavision typically provides quite a graceful filmpath.

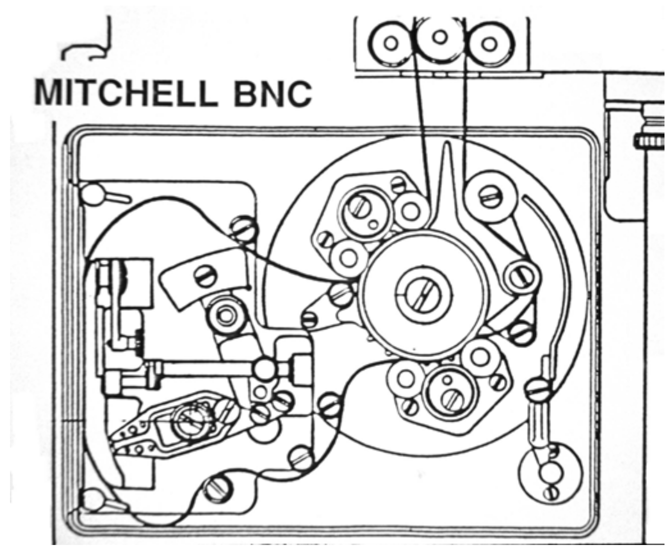


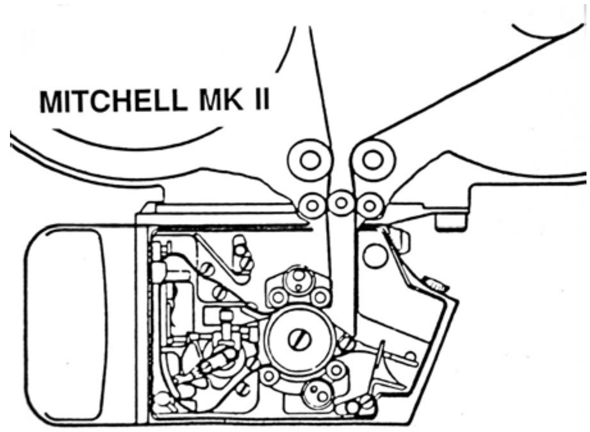
VISUAL - SLIDE:
Film threading - Wilcam W-7.

Here is Geoff Williamson's High Speed VistaVision. The path is somewhat serpentine but the first idler is on a tension arm and all radii are generous.

VISUAL - SLIDE:
Film threading - Mitchell BNC **.**

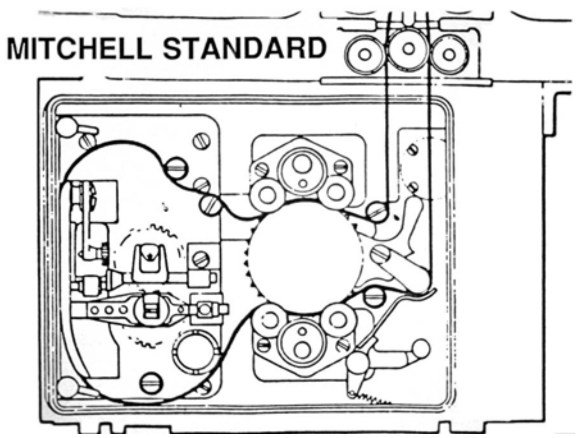
And back to the Mitchell box. The BNC





VISUAL - SLIDE:
Film threading - Mitchell MK II.

The Mark II.



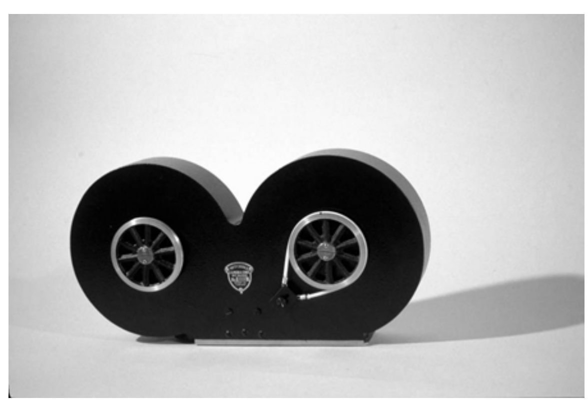
VISUAL - SLIDE:
Film threading - Mitchell Standard **.**

And the Standard.

From these slides, it is easy to see that the Mitchell camera movement, especially the Standard, forces the film to negotiate a particularly sharp turn around a relatively small diameter "Feed Idler Roller," at .366 (three hundred and sixty six thousandths of an inch.)

The first attempted solution was an effort to remove variations in the amount of stress.

VISUAL - SLIDE:
Fries Teflon 'O' ring brake **.**

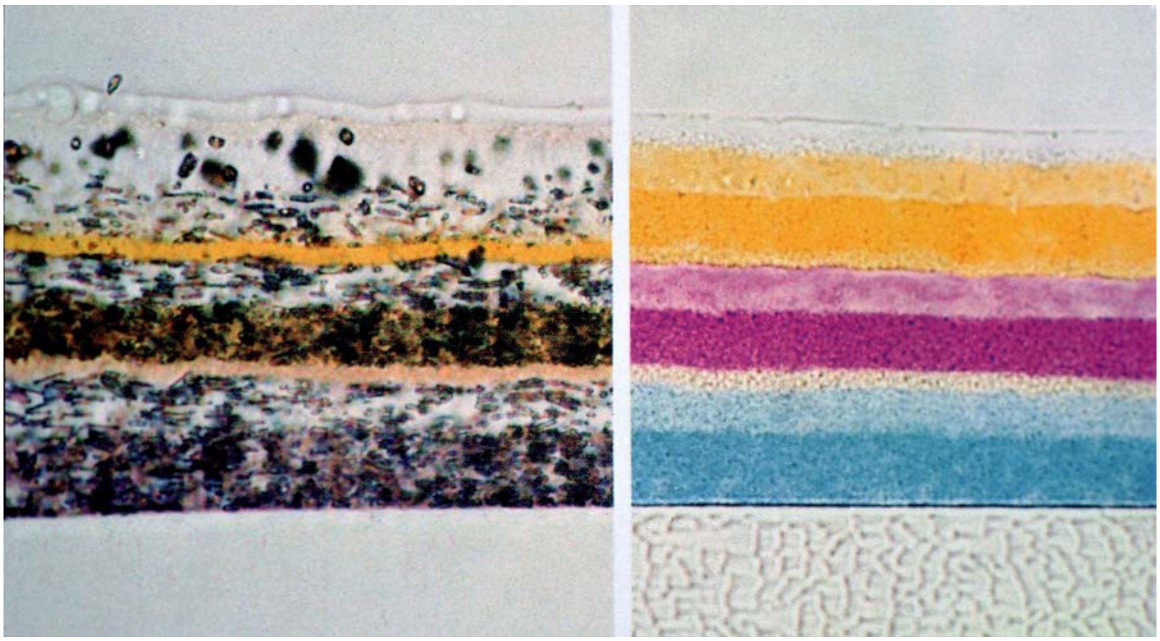


This was done by applying a braking force to the feed side of the magazine. A teflon 'O' ring was mounted to the pulley and attached to a spring tensioner. Approximately sixteen inch pounds of tension was applied to the 'O' ring. This approach, while not actually eliminating stress, sought to at least render the stress constant, so that while the stress desensitization may still be occurring, it would at least be uniform and not exhibit the fluctuation or flicker that attracted attention to it. For some months, this remedy has been available, from Fries Engineering in Los

Angeles, as a kit that can be retrofitted to Mitchell magazines.

This strategy is no doubt beneficial, but in the experience of Apogee camera crews, the results were not sufficiently reassuring, and the problem persisted.

Meanwhile at least one of the filmstock manufacturers was engaged in a major effort to remedy the situation within the emulsion itself.

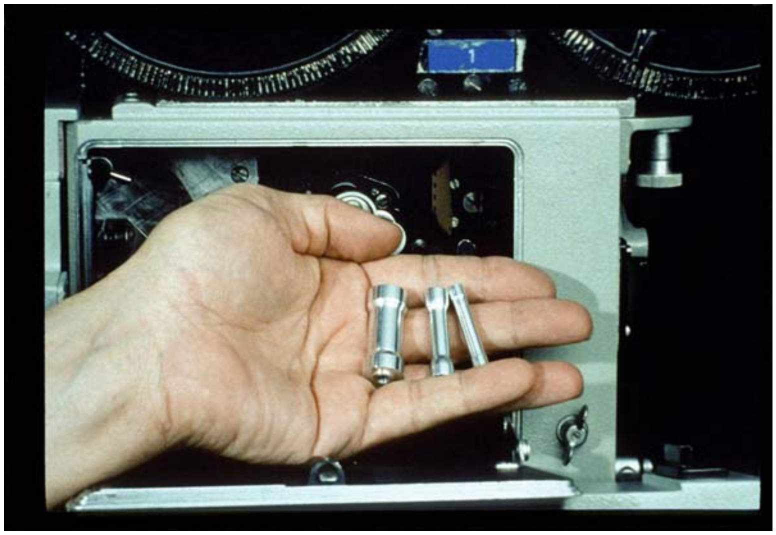


VISUAL - SLIDE: Cross section through emulsion.

In this approach at least some of the reasoning focused on what is known in the jargon of the trade as the "gel to junk ratio," by which is meant the ratio of gelatin to crystals in the emulsion. It's not clear what stress-related changes may actually have been effected but again, for Apogee camera crews, the problem persisted.

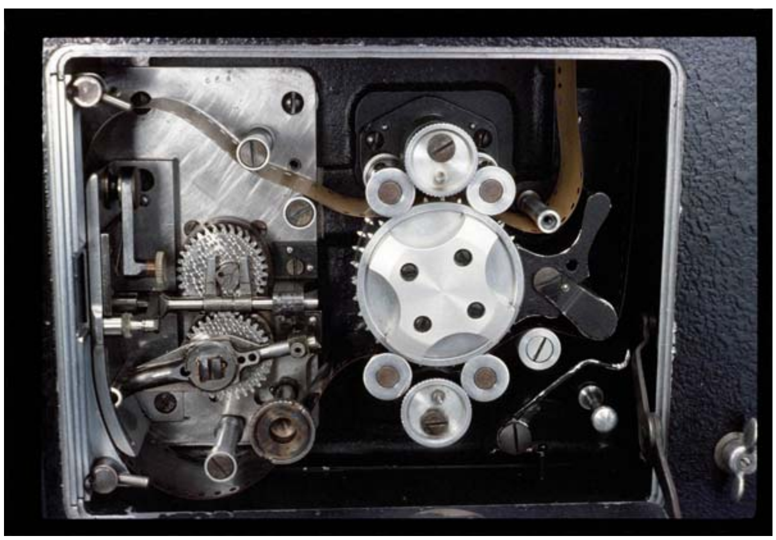
By this time, the accumulating evidence and experience was pointing to the reasoning that, since the stress was a mechanically induced phenomena, the solution was most likely to be found in a modification to the camera mechanism, in spite of the oft repeated comment that the Mitchell camera movements were renowned as the most effective steady and reliable pieces of machinery in the motion picture industry. However, the design dates back to the thirties and forties and could not possibly be expected to have anticipated the radical restructuring of the basic silver halide crystal that has occurred in recent years.

So, in response to all the mounting evidence, Apogee's Senior Cine Technician, Richard Alexander, machined a new "Feed Idler Roller" to replace the standard three eighths roller in the Mitchell Standard. The new roller was approximately eleven sixteenths in diameter. Meanwhile, to facilitate a comprehensive understanding of the effect that such changes might have, I machined an unusually small "feed idler roller" at about a quarter inch in diameter, about as small as it is possible to fit to the camera.



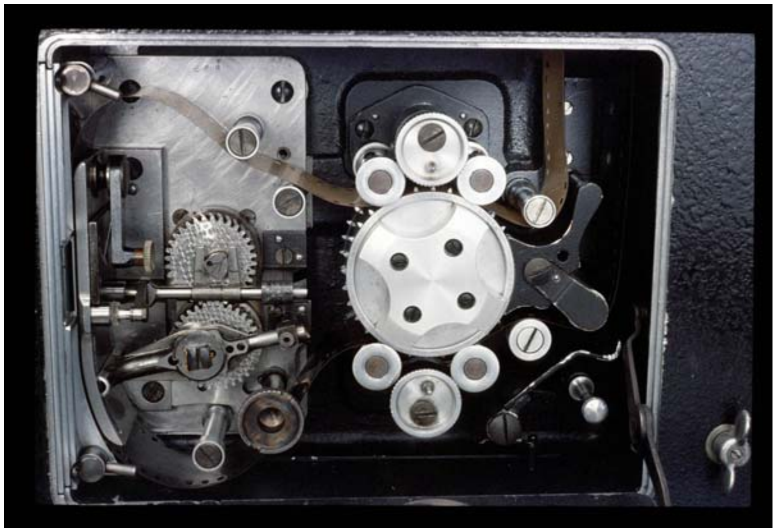
VISUAL - SLIDE: Three different rollers in hand.

Here are the three rollers we used for the tests.



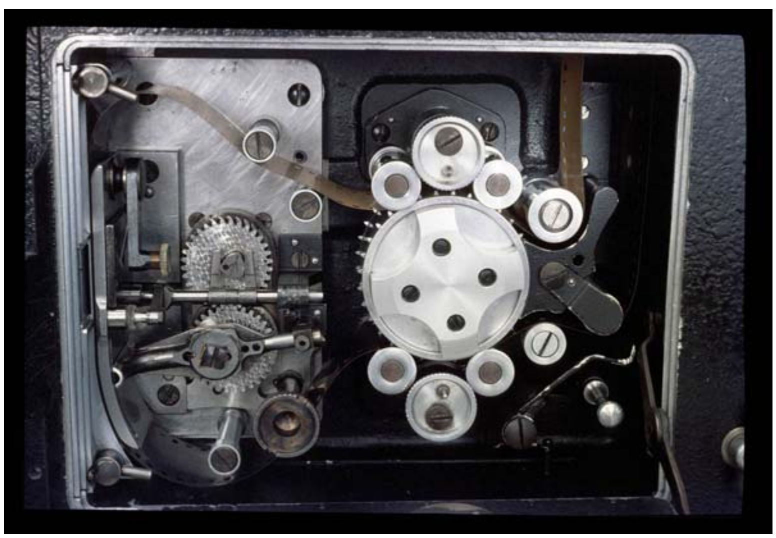
VISUAL - SLIDE: Mitchell with .255 Feed Idler roller **.**

Here is the quarter inch roller installed.



VISUAL - SLIDE: Mitchell with .366 Feed Idler roller installed **.**

Here is the conventional Feed Idler roller.



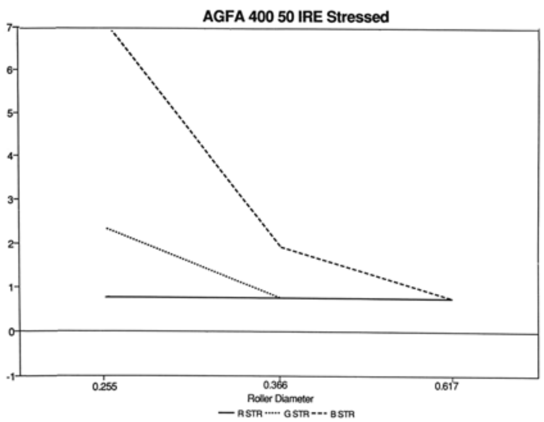
VISUAL - SLIDE: Mitchell with .617 Feed Idler Roller installed **.**

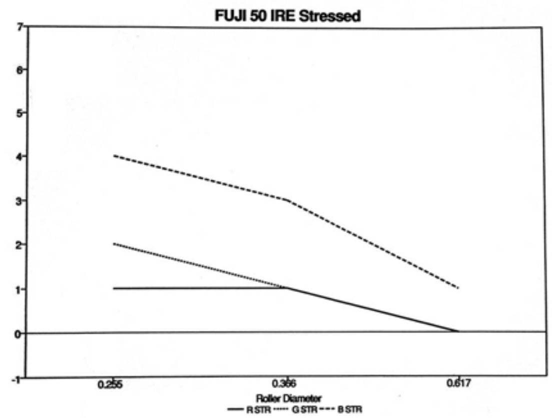
And here is the large Feed Idler roller, which I have dubbed the "Alexander Roller."

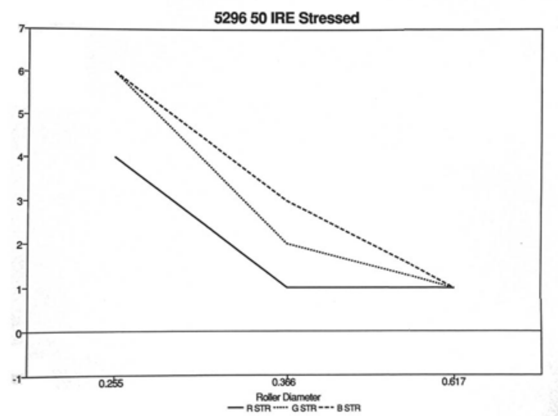
We then designed a test program that called for virtually all of the camera negatives Apogee uses to be tested with each of these rollers. Moreover, in addition to simply running the camera under normal conditions, we undertook to deliberately interfere with the feed pulley of the magazine. By this I mean that the feed pulley was firmly and repeatedly pinched so as to produce an exaggerated shock to the film as it negotiated the first roller in the camera body. The results were profoundly revealing, and we're going to take a look at them now.

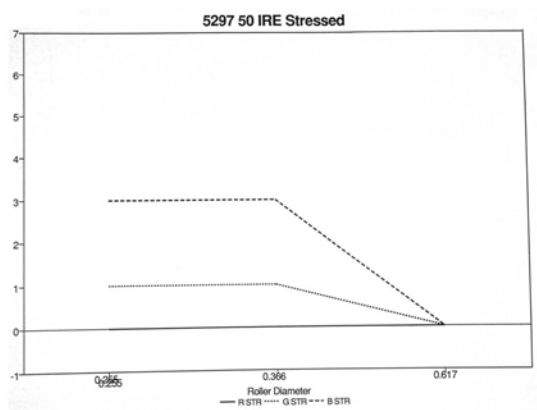
VISUAL - FILM: Test film **.**

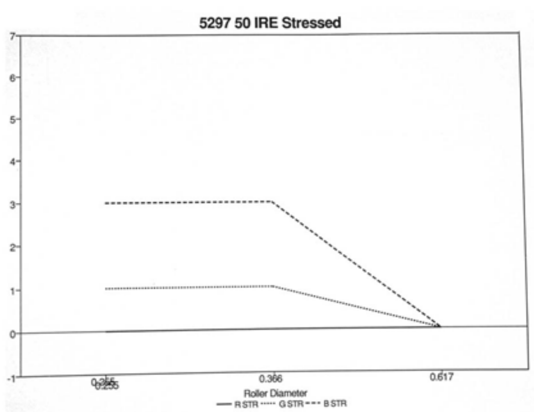
While the impact of the different roller dimensions is visually compelling in watching the running footage, we needed also to quantify the results so that the effects could be also displayed as graphic data. This was accomplished by running the test footage on a telecine and using the waveform monitor to measure the effect on each color record independently. Again, the results are most compelling.

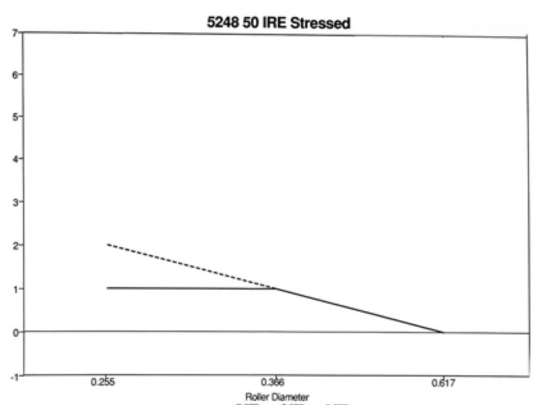


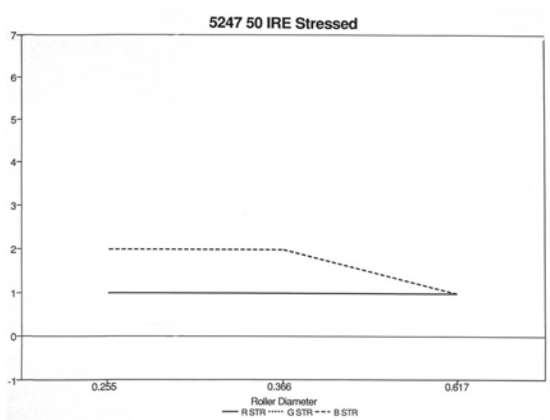


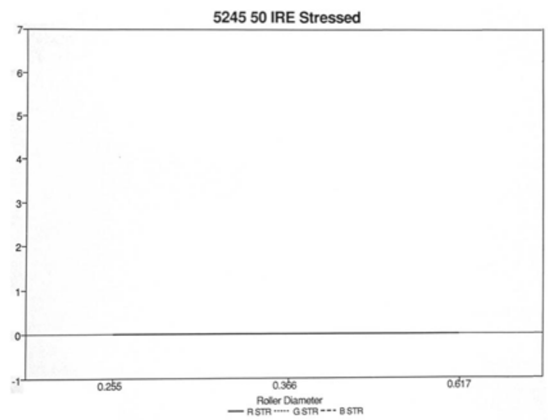




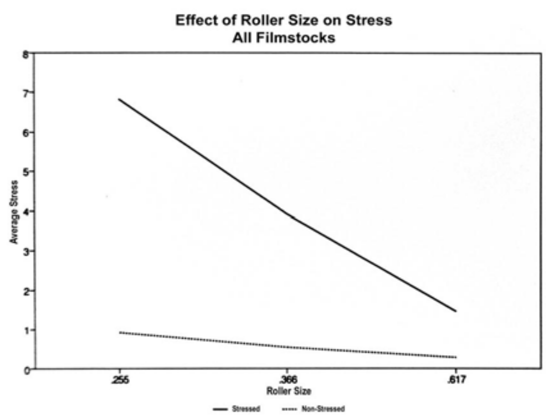








Finally, this is a composite - or average - of the various filmstocks vulnerability to stress in relation to Feed Idler roller size.

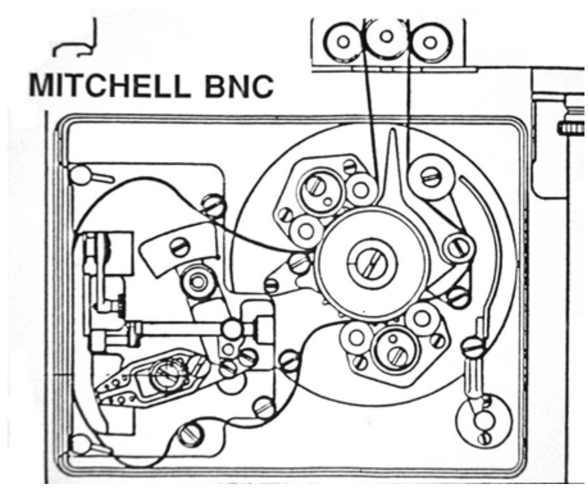


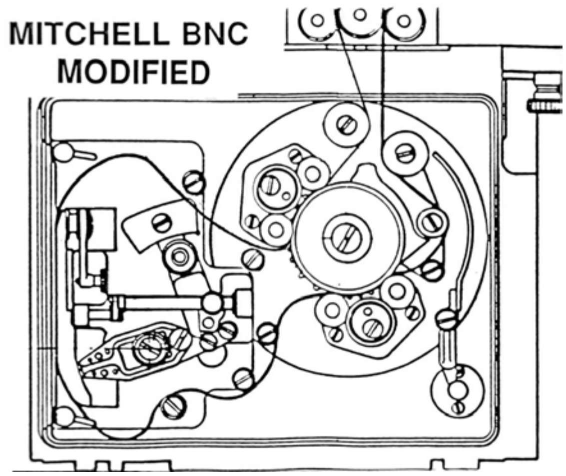
Having concluded that we had, at long last, slayed the dragon, it did not take long to realize that we had a duty to the professional community to share this knowledge. This we proceeded to do, and have shared our findings with our cinematographer colleagues as well as camera builders and filmstock manufacturers.

In the course of our discussion with colleagues, we learned that other efforts had been ongoing, and we requested permission to share this work in this forum also.

VISUAL - SLIDE:
Conventional BNC Mitchell **.**

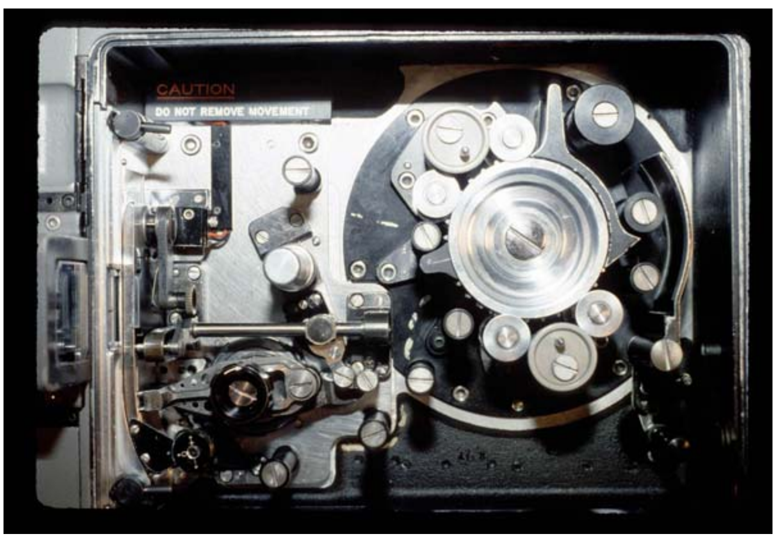
This is an illustration of the film path for Mitchell BNC camera. We can see that, again we come upon a fairly tight turn as we engage the drive sprocket.



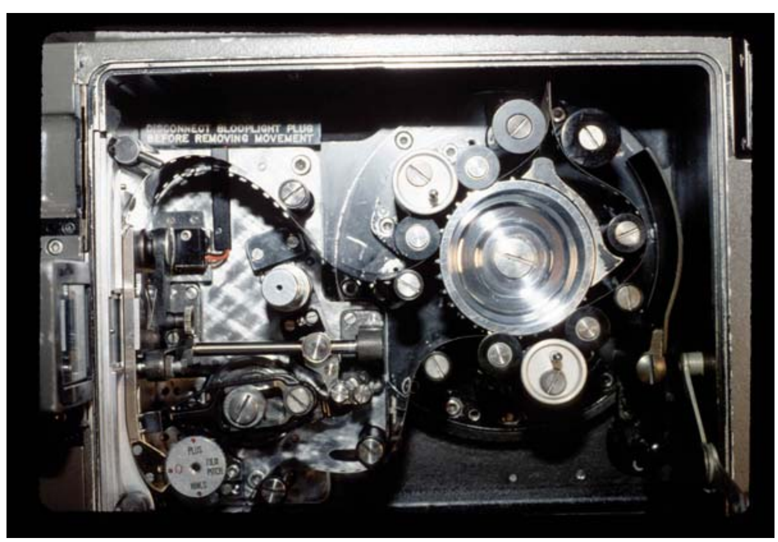


VISUAL - SLIDE:
BNC modification **.**

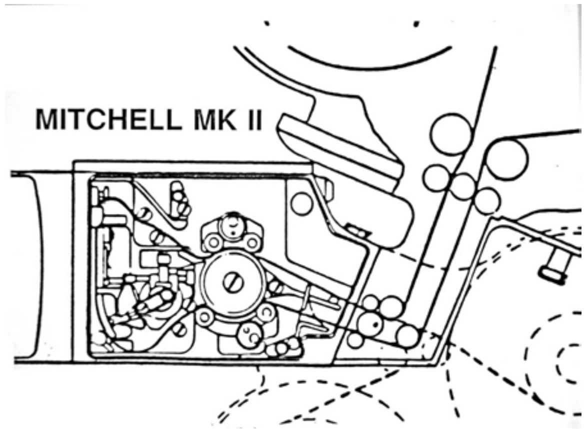
The designers of this modification added a large diameter "feed idler roller" where there was none at all previously. To fit it, they had to move the "Sprocket Guide Roller" assembly counterclockwise around the drive sprocket, and also they had to relieve, which is to say, remove, a substantial amount of the "stripper."



VISUAL - SLIDE:
BNC un-modified - photo **.**



VISUAL - SLIDE:
BNC modified - photo **.**

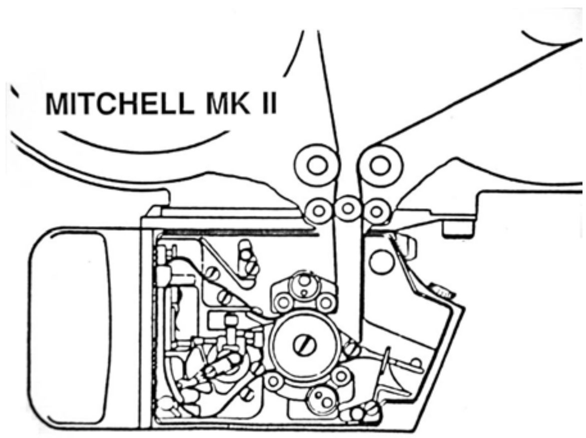


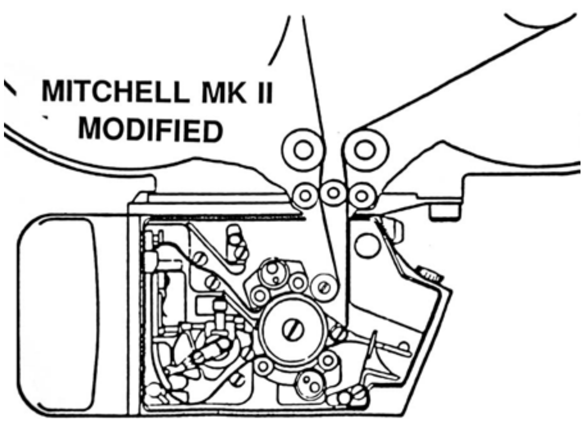
VISUAL - SLIDE:
Mark II. (Back magazine position.)

The Mitchell Mark II presents a similar problem. Although let's look first at the Mark II with the magazine loaded on the back of the camera. Here we can see that the film path through the camera is quite smooth and involves no excessively tight radii.

VISUAL - SLIDE:
Mark II. (Top magazine position.)

On the other hand, using the top magazine position will present difficulties. The obvious solution is to simply use the back magazine mount, but if it is necessary to use the top position, then some fairly radical modifications are required.

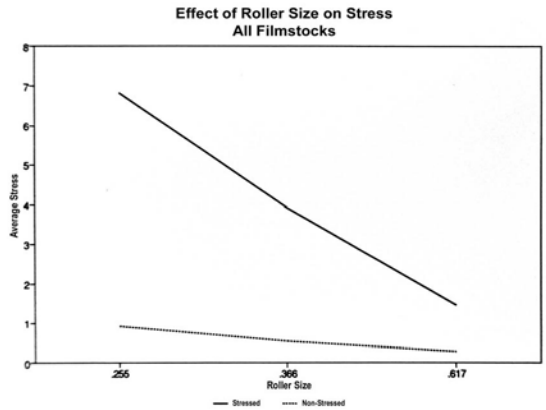




VISUAL - SLIDE:
Mark II. (With modifications.)

Here we can see that the "Sprocket Guide Roller" has been moved slightly forward around the drive sprocket towards the gate. This provides a little room to add a large diameter "Feed Idler Roller". Unfortunately, the relocation of the "Sprocket Guide Roller" will entail modifications to the stripper on the front side of the sprocket.

VISUAL - SLIDE:
"Effect of Roller Size on Stress"



In summary then, we have learned that relatively modest alterations to internal camera mechanisms not only demonstrably alleviate the current problems, but will likely help permit film manufacturers to continue to evolve ever faster and more effective filmstocks into the next century. Equally important, the designers and builders of the cameras of tomorrow will now have a better understanding of the mechanical handling requirements for future high performance filmstocks.

One parting caveat: These recommended modifications are not a panacea; obviously, extreme care should be exercised in all film handling

List of Visuals