digital film technology

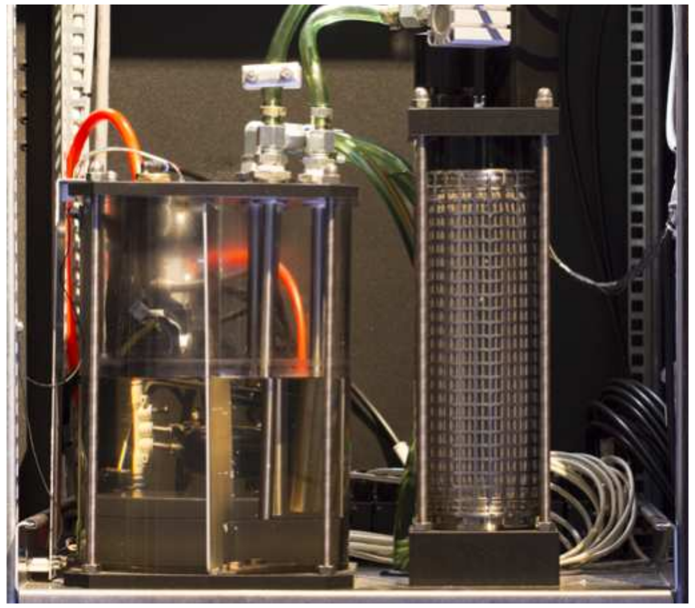
# Rubber vs Metal

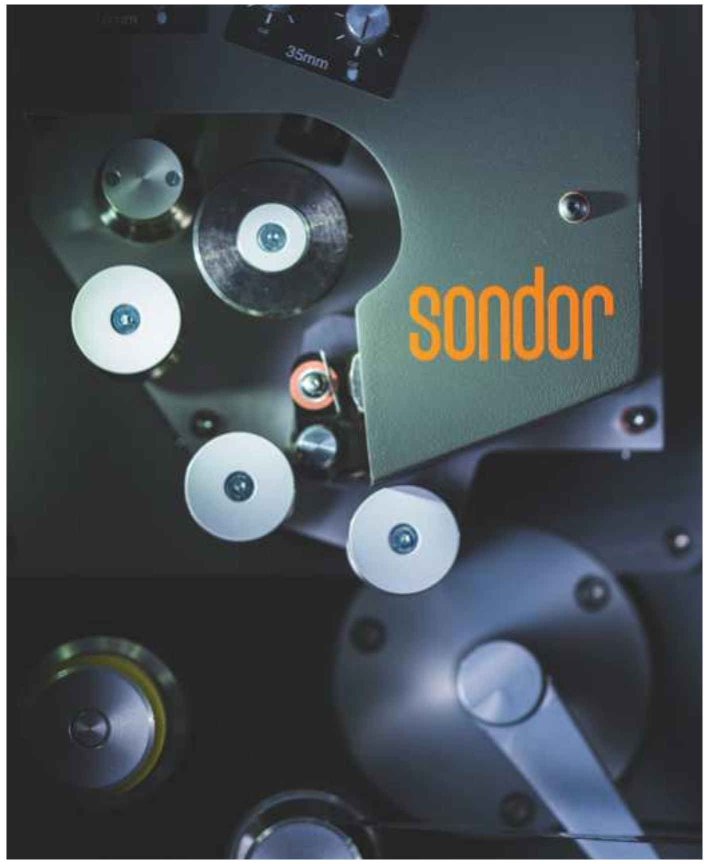
## Challenges of archive film material for film scanner transport design

# white paper


standing the test of time










film scanner transport design

# Challenges of archive film material >>>

Film archives located around the world have collected and stored films for over a 100 years. Among them are many great historical masterpieces, which require long-term preservation for future generations. This material, aged over decades, is deteriorating, and very often has reached the end of its lifetime.

Key decisions have to be made whether to:

1. Digitize the material
2. Create an analogue copy
3. Let it die

Digitized film content (where the film has been scanned and converted to data), has a number of advantages over the alternatives. Firstly, it is easy to handle, manage, edit, and make available to the mass market - either for cataloguing or commercial sales, as more and more online services offer access to digitally available archive content for professional or end customer usage. Secondly, the process of digitizing the film material allows the film to be preserved in a new digital format; either for short and medium term data retrieval or for long term preservation by the use of digital restoration techniques.

This white paper identifies the most important criteria to consider when designing a film scanner transport system, suitable for handling the complexities of historically aged and delicate physical film material.

| Application/Market | Commercial & DI probability of occurance | Archive probability of occurance |
|---|---|---|
| Virgin film material | high | n/a |
| aged film material | n/a | high |
| shrinkage | low | high |
| bending | low | high |
| warping | low | high |
| buckling | low | high |
| damaged & weak splices | low | medium - high |
| damaged perforations | low | medium - high |
| missing perforations | low | medium - high |
| norched edges | zero | medium - high |
| broken edges | low | medium - high |
| scratches | medium | high |

Table -1 Mechanical conditions of DI and Archive film material

## Film handling requirement of different film materials

When designing an appropriate film handling system, the challenge is to ensure that the transport system can accommodate the different requirements of the Commercial and Digital and Archive markets – as well as ensuring ISO film standards are met.

Table 1 compares major mechanical conditions of film material normally used for the different applications. For Commercial, Digital Intermediate (DI) applications, it is likely that film material is virgin film material, original color negative (OCN), in perfect mechanical condition. Film transport for these markets are therefore more or less the specifications found in the related ISO standards for film formats .

As you can see from Table 1, the requirements for Archive applications are much greater – and the prevalence of virgin film material (OCN) is extremely low. In Archive applications, it is likely that the film to be digitized is damaged and demonstrates multiple mechanical defects – such as shrinkage, bending, warping, buckling, weak or bad splices, damaged or missing perforations, notched or broken edges. In addition, a film scanner transport system will also need to adapt to numerous film format (gauge) specifications - ranging from small gauge 8mm through to large gauge 70mm IMAX, as well as accommodate likely chemical and environmental decay, typically seen in aged material, such as fungus, mold, stickiness and vinegar syndrome.

The challenge when designing a film transport system for the Archive market is to fulfill the various (un-)documented film standards as well as manage a multitude of mechanical, chemical and environmental defects in a sensitive and gentle way.





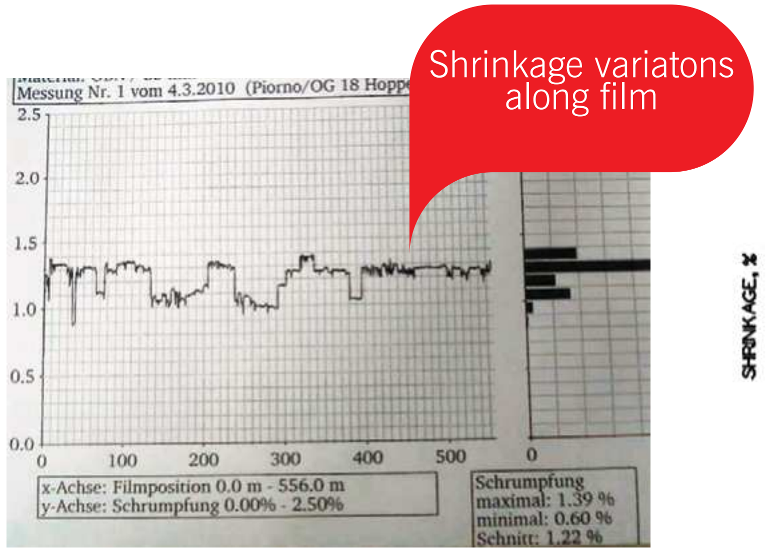



*Figure 1*

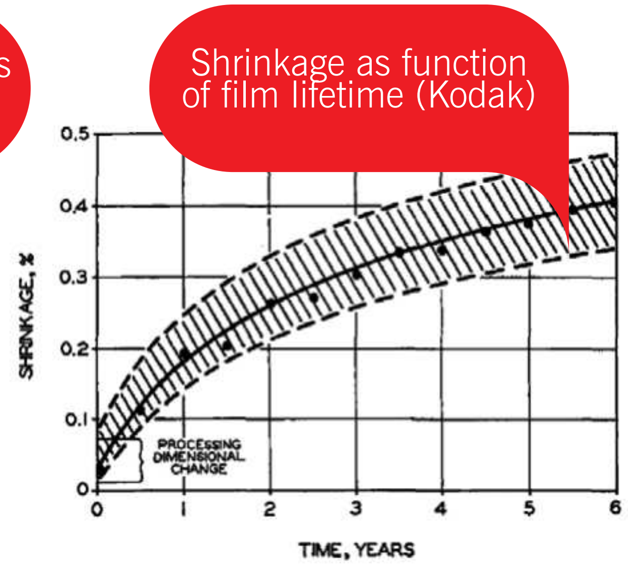



*Figure 2*

*Reference : Adelstein, Peter, and Calhoun, John M., SMPTE Journal, Vol 69 (reprint from March 1960)*

## Overcoming the issues

A suitable film transport system needs to not only be capable of managing a range of film formats and standards, but be designed to overcome or mitigate the issues identified in Table 1 at the scanner transport stage.

### Acetate film base shrinkage

is a well-known phenomenon. Many factors can affect how acetate will shrink and there seems to be no exact consensus as to the main reason for shrinkage. The chemical composition of the film base is fundamental, but various factors appear to interact in different ways: original film dimensions, perforations, film emulsion, processing, tightness of roll wind, and conditions of storage, temperature and humidity cycles, from initial lab through to archive and final storage. Therefore shrinkage can and does vary considerably within any given film roll.

Most measurements show values of linear shrinkage of approximately 0.5% normally for young none aged green film materials, through the more typically found extremes of larger than 5% and, in exceptional cases, up to 10% linear shrinkage have been known with a film image that is still worth viewing. Many major archives report that small proportions of their collections have intact images on 4% shrunk film support .

In conclusion: the film scanner transport must be able to handle film up to or greater than 5% shrinkage, preferably an aptitude to apply automatic compensation (speed, dimensions etc.) and measurement, to correct for these likely physical constraints.

### Warped and buckled Film

- One reason for warped and buckled film is acetate decay or vinegar syndrome. A number of environmental factors can contribute to the decay of the base of acetate film including heat and humidity (Figure 3). The film base will begin to shrink which will make the emulsion layer

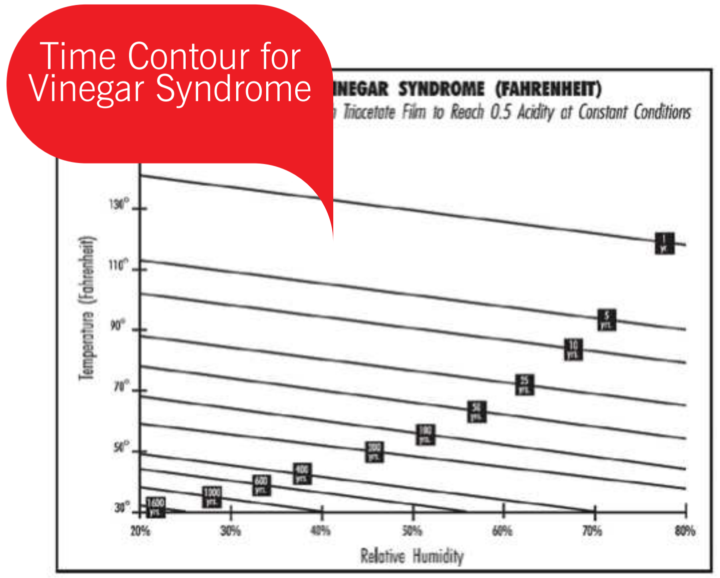



*Figure 3*
*Reference : James M. Reily, IPI Storage Guide for Acetate Film*

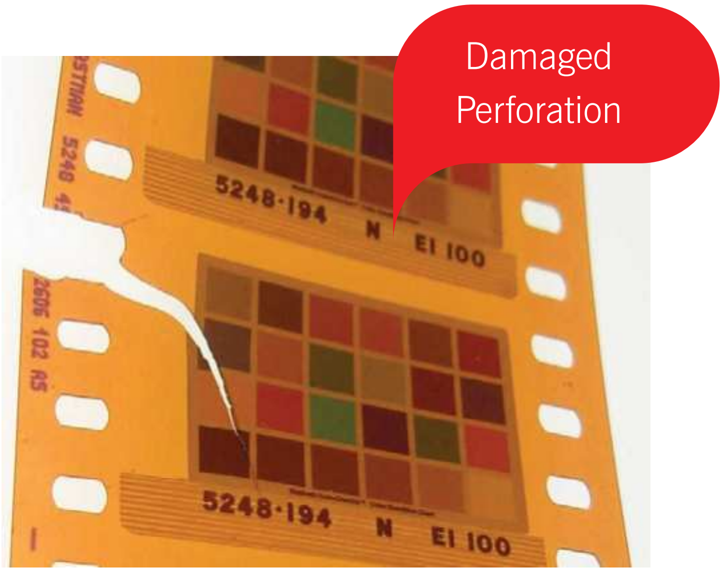



*Figure 4*


*Figure 5*

buckle because it cannot fit on the base any longer. As a result, the film curls, warps or buckles along both length and width. The film will begin to smell strongly as the acetate gives of gasses. The acetic acid that has been released can infect other nearby film, which is why deteriorated acetate film must be segregated from other films. Failure to do this results in long-term damage.

In conclusion: the film scanner transport must be able to handle and successfully manage warped or buckled aged film materials. The transport and film scanning area have to be tolerant to variations of film thickness and gently guide the film, stabilizing it as it is offered to the scan area.

**Damaged or missing perforations** - A recognizable percentage of archived material comes with damaged or missing perforation holes (Figure 4). These may have occurred through the intensive use in sprocket or pin based equipment, such as film projectors and telecines.

Perforation holes reduce the cross section of the film base, effectively creating a physical weakness to the construction of the emulsion base, and can therefore lead to peak tension in the film base.

Usage of curved or guided skid plates will diminish the cross section even more. This together with high tension due to fast acceleration and stopping leads to perforation damage and very often to film breakage and tearing.

In addition, another issue commonly seen relates to imperfect splices, which can simply cover the perforation hole potentially leaving film vulnerable to breakage at these spliced sections.

In conclusion: the film scanner transport must provide a relaxed method to handle the film material. It needs to avoid high inertia start stop operations, provide an adjustable film tension, avoid physical contact/stress to the weak perforation (or splice joints), compensate for missing perforation holes, and compensate for damaged holes - whilst at the same time offer no friction between film and mechanics at all times.

**Damaged and Weak Splices** - In aged material, splices – even perfect splices - are very often the weakest piece in the film (a chain of links is only as strong as the weakest link in that chain). Depending on environmental circumstances – such as temperature, humidity and available chemicals - cement and ultra-sonic joints have a tendency to break loose while tape splices peel off the film itself.

Imperfect splices can also result in local changes to the film thickness and film width, often spoiling or occluding the perforation hole.

In conclusion: the film scanner transport must manage low and adjustable film tensions and limited bending of film. It needs to provide an adjustable film speed and be tolerant to changes in film thickness and film width due to physical bad splices.

**Avoiding of Dust** - If the film material is in pristine condition it will not be a challenge to the transport system, however it is absolutely necessary to reduce wear and tear to the material to avoid the generation of emulsion and other film dust.

In DI scanning this can be managed by post possessing, which can be cost effective under a DI commercial process. However, in the time and cost driven archive world this is not practical, regardless of the physical implications on the material for future potential use. The generation of dust that is visible in the scan area is often exacerbated by the wrong kind of transport system. Typically a pin or sprocket driven scanner transport system will add mechanical friction to the perforation holes which leads to both physical wear and tear as well as liberating small particulars of film base onto the scan area, resulting in specks or spots of dirt been ingested as part of the digital master.

In conclusion: the film scanner transport must be capable of generating no friction between film and servo transport mechanics as seen with pin or Sprocket driven scanners.

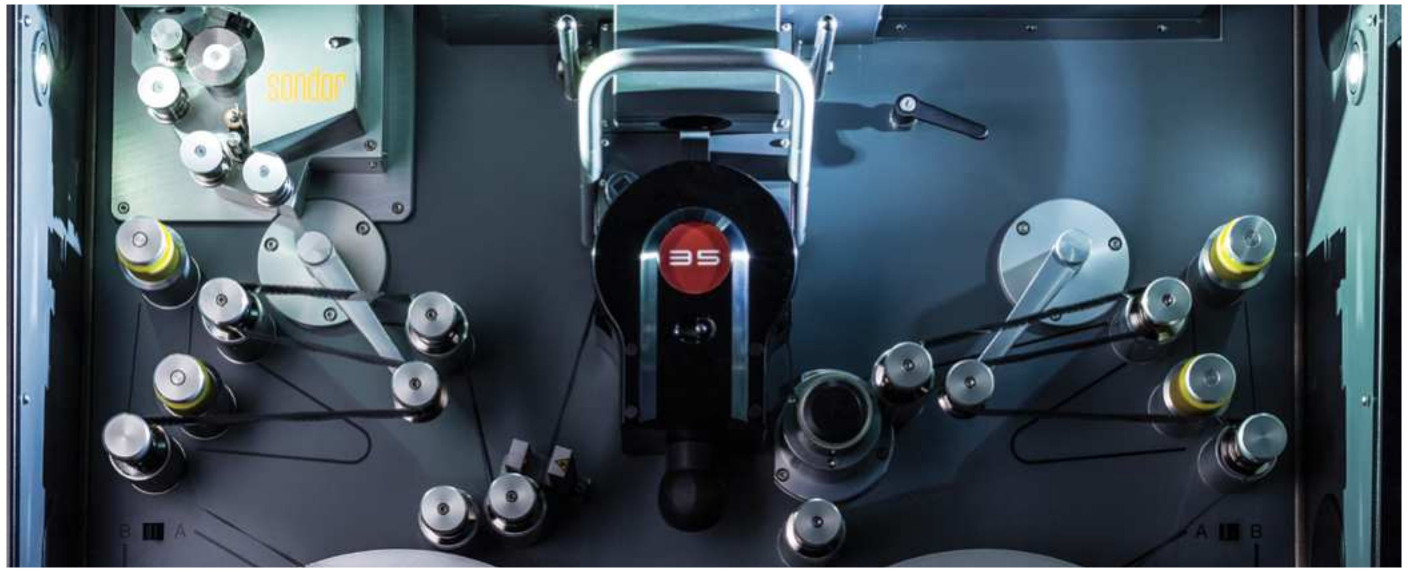


*Figure 6 Scanity film transport system*

Film scanner transport for Archive applications must therefore:

1. Be able to handle film up to larger than 5% shrinkage, ie. automatic compensation (speed, dimensions etc.) and measurement

2. Be able to handle and manage “warped” aged film materials. The transport and scanning areas have to be tolerant to variations of film thickness. Moreover gently guide the film, stabilize as it is offered to the scan area

3. Have a relaxed handling of the film material, avoiding high inertia start stop operations, providing low and adjustable film tension, avoid physical contact/stress to the weak perforation, compensate missing perforation holes, compensate for damaged holes and have nil friction between film and mechanics

4. Provide low and adjustable film tension, limited bending of film, adjustable film speed, tolerant to changes in film thickness, film width due to bad splices

5. Avoid friction between film and mechanics

| Requirement | pin / sprocket Scanner |
|---|---|
| Allow larger than 5% shrinkage | Only with special Pins and Sprockets, resulting in poor H&V (Horizontal and Vertical) transfer stability. |
| Automatically adapt to shrinkage variations in film | not possible |
| Tolerant to variations in film thickness | very limited |
| Tolerant to variations in film width | very limited |
| Avoid high inertia start/stop operation | push & pull operation |
| No physical contact/stress to perforations | pin/sprockets touch perforations |
| Compensate missing perforations | very limited |
| No friction between film and mechanics | friction due to pin or Sprocket insertion, friction due to skid plate |

Table - 2 Requirements Pin & Sprocket based Transport

After having collected the set of requirements needed to fulfill the challenges of Archive applications, we now have to select the right technologies, which are able to realize these needs.

## A sprocket and pin based approach

Although many pin and sprocket based film scanners have been successful in the past decade, Table 2 shows that such a transport is not able to fulfill the set of requirements identified for Archive applications.

In the past, manufacturers produced film scanner solutions predominantly for virgin OCN film ingest for the video commercials or feature film / DI sectors. Scanners needed very precise ways of image stabilizing during the scanning process, so they tended to use pin insertion into the film perforation hole as a means of stabilization. Quite often, this technology was used to push or pull the material though the scanner, sometimes on its own and sometimes with sprocket drive.

Whilst this technology suited perfectly the DI requirements for high levels of H&V (Horizontal and Vertical) image stability, particularly as the OCN was usually in a good or new condition, it is however not suitable for aged and historically important film archive management, as both pin insertion and sprocket driven scanners solutions place enormous physical stress on the film.

Typically pushing and pulling film via the insertion of pins, or the drive of the film via sprockets causes wear and tear to the material, which can create film damage and loss of confidence for the film archivist. This film drive method via the insertion of pins/sprockets becomes virtually impossible to use if the film material in question has any age-related constraints. If the film material in question is in good condition, at best the resulting image scans will be stable but likely covered in specs of dust (emulsion scrub) created by the physical pin insertion or sprocket drive.

## A capstan and roller-gate approach

As you can see from Table 3, a capstan and roller gate approach is almost a perfect match for aged film requirements. It is the reason why dft’s Scanity film scanner family is based on a capstan and roller gate transport system.

## Roller Gate

In order to minimize film friction and abrasion, dft’s approach is to build a film path without any fixed guides (skid plate, guiding edges) in the direction of film travel by using an all

| Requirement | Capstan & Roller gate |
|---|---|
| Allow larger than 5% shrinkage | yes |
| Automatically adapt to shrinkage variations in film | yes - automatic updation |
| Tolerant to variations in film thickness | yes |
| Tolerant to variations in film width | yes - with limits |
| Avoid start/stop operation | continuous transport |
| No physical contact/stress to perforations | touch free optical perf detection |
| Compensate missing perforations | yes |
| No friction between film and mechanics | no - friction due to roller gate |

Table - 3 Requirements Capstan & Roller gate based Transport

roller design as shown in Figure 6. Most important is the precision roller-gate that offers unparalleled smooth and safe film handling across differing film formats, ranging from 35mm, 16mm and 8mm. (See figure 8)

## Capstan drive and optical perforation detection

Smooth transport of film material is imperative as it reduces the stress on the often delicate and aged material. Scanity and Scanity HDR solve these requirements using a high precision rubber-coated capstan drive solution. The capstan allows for a combination of gentle and relaxed contactless film drive, but yet overcomes the usual film instabilities found typically with capstan driven solutions, by use of a touchless patented optical perforation detection system. Dedicated camera technology assesses the stability of the film transfer and uses this information to provide industry leading H&V (Horizontal and Vertical) image stability and at up to real time speeds.

Typical film stability is specified on Scanity and Scanity HDR at fractions of a pixel at 4K. Virtual pin performance steadiness without any downsides.

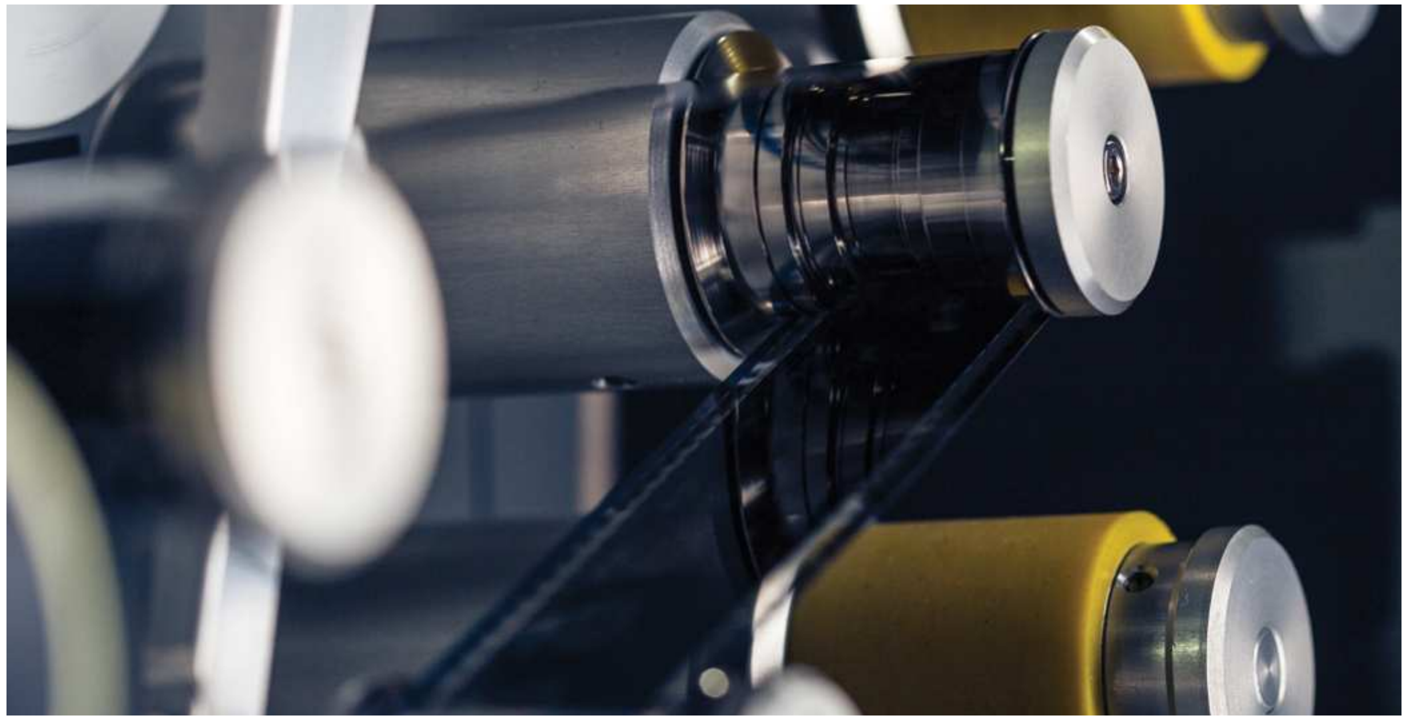


*Figure 7*



| No. | Requirement | Solution realized in Scanity |
|---|---|---|
| 1 | Ability to handle film > 5 % shrinkage, i.e. automatic compensation (speed, dimensions etc.) and measurement | Scanity Capstan Drive – offers as part of its servo system larger than 5% automatic shrinkage compensation and easily handles the typical film shrinkage percentages that aged film materials suffer from. |
| 2 | Ability to handle and manage “warped” aged film materials, i.e. transport & scanning area have to be tolerant to variations of film thickness. Moreover gently guide the film, stabilize as it is offered to the scan area. | The combination of state of the art servo system, rubber coated capstan, and roller-gate provides unrivalled handling and management for “warped “aged film materials. During the handing process, the film material is gently guided to the scanning area, assessed during its run up, and interrogated to maximize stability as it is offered to the scan area in the most sensitive manner |
| 3 | Relaxed handling of film material, avoid start stop operation, low, adjustable film tension, avoid physical contact/stress to the weak perforation, compensate missing perforation holes, and compensate damaged holes. No friction between film and mechanics. | Scanity Capstan Servo, has no sprocket or hard mechanical pin insertion as part of its film servo drive train, but uses a capstan instead, thus liberating a clean and sensitive handling of the film material |
| 4 | Low and adjustable film tension, limited bending of film, adjustable film speed, tolerant to changes in film thickness, film width due to bad splices. | The combination of state of the art servo system with tension control, rubber coated capstan, and roller-gate with large diameter– offers unprecedented handling of splices and cement joints , limiting the most likely damage to old and brittle film stocks, that of unwanted breakage. |
| 5 | Avoid friction between film and mechanics to reduce dust generation. | The all roller based transport layout, the roller-gate, the touch free perforation detection avoids generation of dust by reducing friction to the absolute minimum |

Table - 4 Scanity matching “X“ factor

*Figure 8 Lens Gate Assemblies*

## Conclusion

Scanity and Scanity HDR uses a state of the art capstan driven film transport system developed over decades of research and development, resulting in its current patented roller based Lens Gate Assembly (LGA) strategy.

This strategy delivers high levels of H&V (Horizontal and Vertical) image stability at user definable speeds, up to real-time, whist still providing flexibility in addressing the limitations of difficult to manage aged film materials.

Delivering confidence in the management of historically important film material for future generations.

“dft making sure the past has a future! “

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