

IMAGE RESOLUTION OF 35MM FILM IN THEATRICAL PRESENTATION

1. Introduction

In the framework of the activity of ITU-R Study Group 6, intended to specify large-screen theatrical presentation of programs available in the form of digital imagery signals (“Large Screen Digital Imagery” or LSDI), tests were performed to determine the end-to-end resolution performance of 35mm cinema film from negative photography through to print projection in typical motion picture theaters today.

This performance was considered to be an important reference point, because the vast majority of motion pictures are produced for distribution in the form of 35mm release prints, so that the main perceptual reference performance for the 35mm cinema today is that which corresponds to theatrical projection of 35 mm release prints.

However the study of this reference point did not imply the assumption that the performance of LSDI should necessarily be equivalent to that provided by theatrical exhibition of 35mm release prints of feature films. LSDI could be of higher quality than today’s 35mm cinema film presentation, equal to it, or of lower quality depending on the application.

It is important to underline that the tests were not conceived as a research project intended to measure the ultimate resolution possible of the 35mm cinema film system nor to predict what could be achieved with developmental equipment, film stocks, processing, or projectors. Rather, these end-to-end 35 mm cinema film resolution tests utilized existing state-of-the art 35mm cinema film equipment, film stocks, processing, printing, and projection in actual day-to-day use for feature film production, post production, processing, printing, and exhibition in theatres worldwide. Thus, the tests studied the practical 35mm cinema film resolution that is achieved in normal operation today.

To this end, qualified professionals and organizations that operate in the international cinema feature film industry were called upon to participate in the production of the 35mm test films, and their contribution is gratefully acknowledged.

The tests were structured in two phases. During the first phase, the tests evaluated the typical resolution obtained on theatrical presentation of a 35mm release print film. During the second phase the test evaluated the typical resolution obtained on theatrical projection of a 35mm answer print film¹.

Section 2 of this paper summarizes the procedure used for the tests, Section 3 gives some information on its implementation and Sections 4 and 5 provide a summary of the objective and subjective results obtained.

2. Procedure used for the test

The test followed the procedure outlined below, which had been submitted for endorsement by an international group of experts.

- A resolution test pattern was photographed in the USA on a 35mm negative film stock typical of those used for the production of feature films. Film cameras and prime lenses typical of those used for feature films were used for the shooting, which was performed in the presence of an international panel of

¹ The process to produce a 35mm release print film is to strike a 35mm inter-positive film of the original 35mm negative, then to strike a 35mm inter-negatives of the inter-positive film, and finally to strike the required number of 35mm release prints from the inter-negative films. A release print is thus a third generation copy of the original negative. This approach is used in order to limit the wear and tear of the original camera negative, which could not be replaced if it were damaged. By contrast, the process to produce a 35mm answer print film is to strike it directly from the original 35mm camera negative. An answer print is thus a first-generation copy of the original negative. In order to limit the wear and tear of the original camera negative, answer prints are only made in very small numbers, to be used on some rare occasions, such as the presentation of a movie at a festival.

experts. A second shooting of the same resolution test pattern was made in France with the cooperation of the French Association of Cinematographer (AFC).

- The exposed negatives were developed using state-of-the-art facilities.
- The negatives were then edited to ease implementation of subjective assessment sessions.
- In the first phase of the test, interpositives, internegatives, and release prints were developed and printed in two laboratories as a control check, using state of the art facilities and 35mm film stocks typical of those used for feature films. In the second phase of the test, answer prints were struck from the original negative produced in the first phase.
- Objective measurements of the MTF (Modulation Transfer Function) Curve of the resolution test pattern were taken on the 35mm negatives, the interpositives, the internegatives, the release prints and the answer prints.
- In the first phase of the test, the better of the 35mm release prints was projected in selected movie theaters after verification of the correct performance of the projectors, and an international panel of experts examined the projected images to assess the end-to-end resolution of the 35 mm film chain. In the second phase, the answer print was projected in a Montreal theater, for examination of the projected image.

3. Production of the 35mm test films

3.1 The test chart

The chart used for the shooting contained multiple sine wave test patterns, specially made by Sine Patterns LLC of Pittsford, N.Y. It has an aspect ratio of 1.85:1, and measures 400 mm x 740 mm. The use of a sine-wave pattern was chosen over the more traditional square-wave pattern to permit accurate measurement of the MTF of each stage of the film process, from the original negative, through the inter-positive, the inter-negative, and the release print. These measurements then provided a true concatenation of the MTF's of the individual elements from the chart, imaging lens, and film.

The low contrast range of the patterns ensured that the measurements would be performed on a relatively linear portion of the film transfer curve.

Figure 1 shows the appearance of the test chart.

The test chart contains eight multiburst groups superimposed on a mid-gray background. Four groups are located toward the center of the test chart and four toward its edges. This was done to allow viewers to assess resolution in eight different areas of the projected image. Two of the groups toward the center of the test chart are oriented vertically. This was done to allow assessing both vertical and horizontal resolution.

Each multiburst group consists of 9 sine wave patterns, ranging from 0.375 cycles/mm to 3 cycles/mm.

When the 400mm height of the chart is imaged by a normal lens so as to fill the 11.33mm image height of the film Academy Aperture, the spatial frequencies exposed onto the negative range from 13.25 cy/mm to 106 cy/mm, equivalent to a resolution of 300, 400, 600, 800, 1000, 1200, 1600, 2000, and 2400 Lines per Picture Height (L/PH) for the 9 patterns. To provide additional data points for the test, the chart was also photographed such that 350 mm of the chart height filled the Academy Aperture. This produces spatial frequencies ranging from 11.6 cy/mm to 92.74 cy/mm, equivalent to 262.5, 350, 525, 700, 875, 1050, 1400, 1750, and 2100 L/PH.

The depth of modulation of the multibursts on the test chart was measured, documented and utilized as the reference for the film MTF measurements.

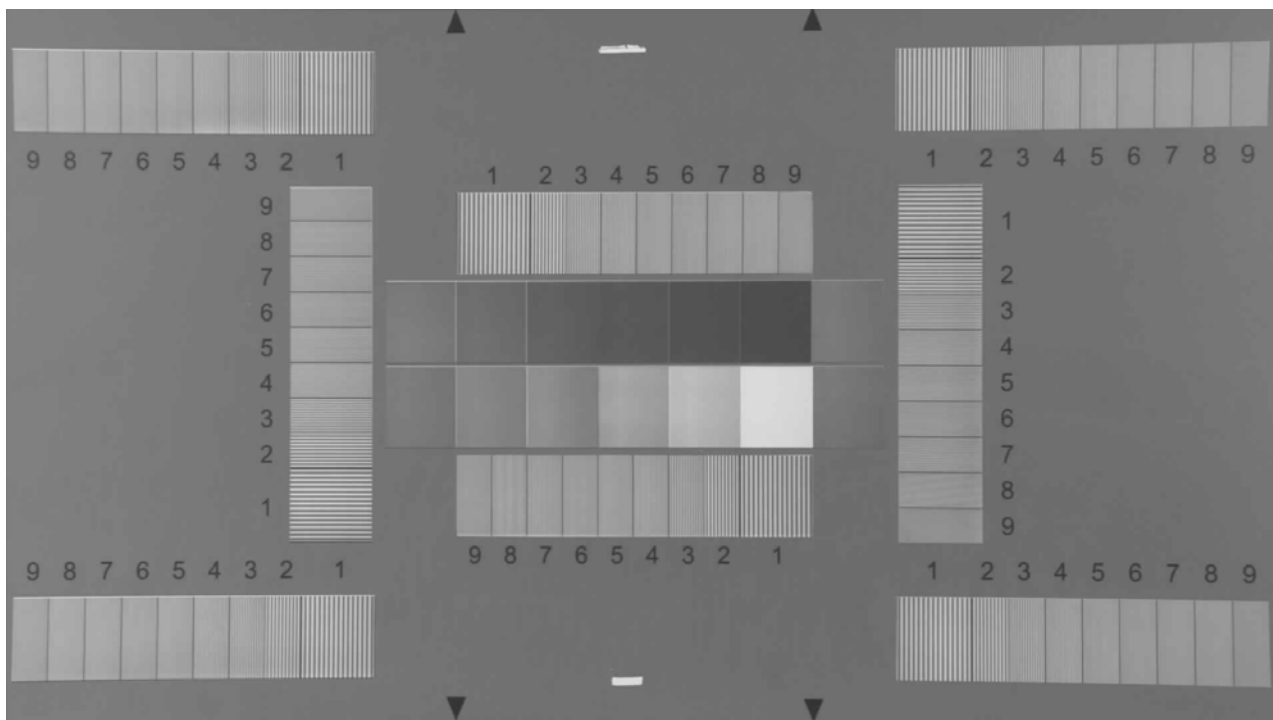


FIGURE 1
Resolution test chart used for the test

3.2 First shooting

The first shooting of the negative film took place on Stage 2 of Panavision in Woodland Hills, CA, USA, on June 27, 2001, and the second shooting took place in Paris at Technovision on January 20, 2003, in the presence of an international group of test monitors.

Two cameras (a Panavision Panaflex Millennium camera, serial number PFX-127M and an Arriflex 435 S camera, serial number 435ES-140) were used to shoot the test chart. The Arriflex camera had been modified by Panavision to accept Panavision lenses.

Two prime lenses (a Panavision Primo-L lens and an anamorphic Panavision Primo Auto Panatar lens) were used to photograph the test chart. The two lenses were used on both cameras since they could be interchangeably mounted on both.

The illumination on the test chart was 200 ft. candles. The lenses were set at a stop of T 5.6.

No filters were used on either lens when photographing the test chart.

The performance of both cameras was measured and found to be within specifications.

The axial MTF of both lenses was measured at the focusing distance and T-stop used during the shooting. The MTF of the Primo-L lens dropped to about 75% of its maximum value at a resolution of 50 cycles/mm, and the MTF of the Primo Auto Panatar lens dropped to about 68% of its maximum value at the same resolution².

² A spatial resolution of 50 cycles/mm corresponds to 1133 lines per picture height on release prints with an aspect ratio of 1.85:1.

Negative film stock type Kodak 5274 was used for the resolution test pattern photography.

The Interpositive was struck on film stock type Kodak 5242 from the original negative.

The internegative was struck on film stock type Kodak 2242 from the interpositive.

The release prints for the first phase of the test were struck on film stock type Kodak Vision Color 2383 from the internegative using a high speed printer.

The answer prints for the second phase of the test were struck from the original negative on film stock type Kodak Vision Color 2383 using a wet gate printer.

3.3 Second shooting

The second shooting of the negative film took place at TECHNOVISION (32, rue Delizy, 93694 Pantin – Paris France) from 10:00 to 13:00 on January 20, 2003 in the presence of an international group of test monitors in accordance with an approved test plan.

A film crew selected by the the French Association of Cinematographers (AFC) did the shooting.

The shooting was supervised by Mr. Olivier Benoist (Director of photography, France), Mr. Philippe Coroyer (Director of photography, France), Mr. Jean-Noël Ferragut (Director of photography, France), Magali Thirion (camera operator, France) and Mr. Jean-Marie Adam (lights and studio set-up, CST, France). It was also supervised by Test Monitors Mr. Vittorio Baroncini (FUB, Italy), Mr. Matthieu Sintas (CST, France), and Mr. Paolo Zaccarian of Italy).

The camera used to photograph the test chart was an Arriflex III 35 (serial number 41212).

The performance of the camera was measured before the shooting and found to be within specifications.

A prime lens (Zeiss Planar 2/50, serial number 6784167) was used to photograph the test chart.

The lens back focus was tested prior to the shooting.

No filters were used on the lens when photographing the test chart.

Negative film stock Kodak type 5274 was used for the shooting. This film stock was indicated as the artificial light stock most widely used today to shoot feature films.

The film used for the shooting was checked by means of sensitometric measurements before the shooting.

4. Objective MTF film measurements

MTF variations along the film production chain

MTF resolution measurements of the test pattern were taken on the negatives, the interpositives, internegatives, release prints and the answer prints. A proprietary microdensitometer of Sine Patterns LL.C. with a slit width of 1 micron was used for the measurements. The results of the measurements on the negatives obtained from the two shootings were very close.

The results of the MTF horizontal response measurements for images photographed with the normal (spherical) lens for the first shooting are plotted on Figure 2 and Figure 3. Figure 2 applies to the first phase of the test (the release print resolution test). Figure 3 applies to the second phase of the test (the answer print resolution test).

In both figures, the horizontal axis shows the spatial frequencies, expressed in lines per picture height (2 lines/PH make up a cycle/PH). The vertical axis shows the modulation of the frequency bursts in the multiburst groups of the test pattern. The MTF response curves have been smoothed to eliminate minor variations in the data samples. The highest MTF response values among groups have been used on all the smoothed curves.

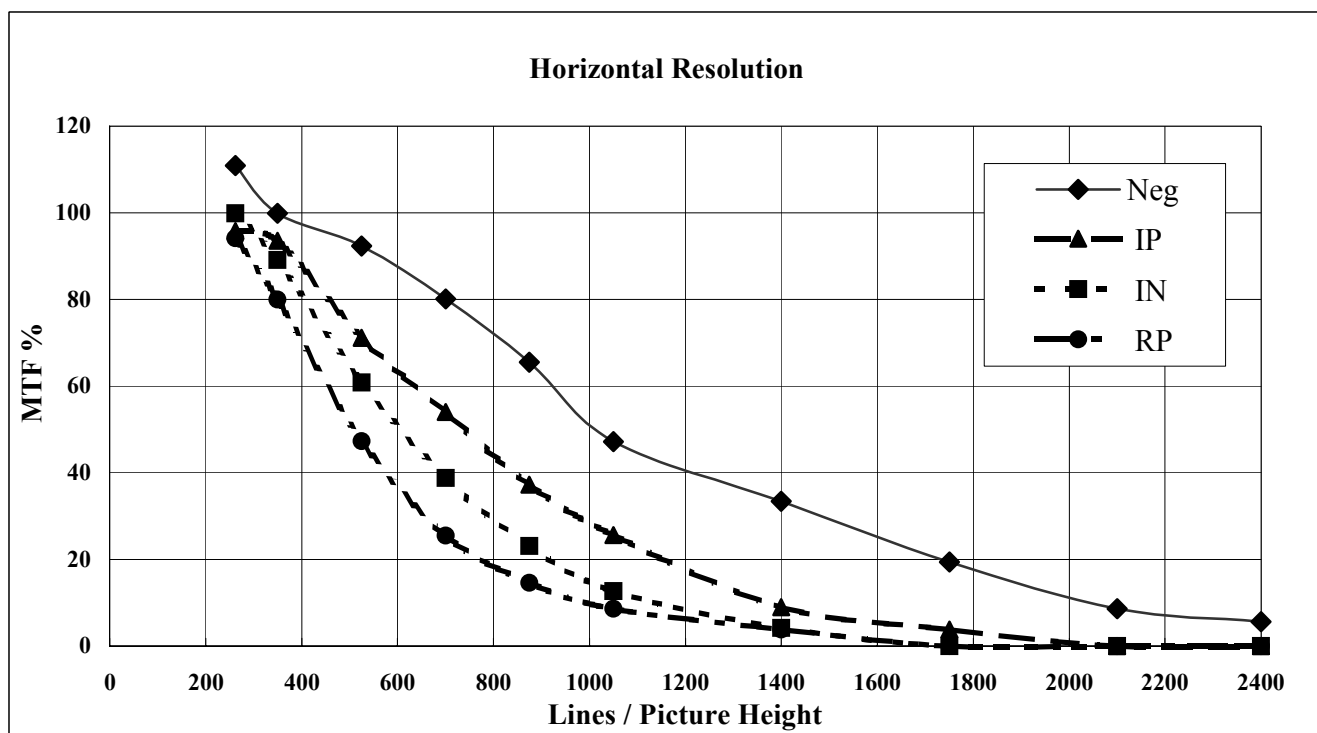


FIGURE 2

Horizontal MTF of 35 mm negative, interpositive, internegative and release print films

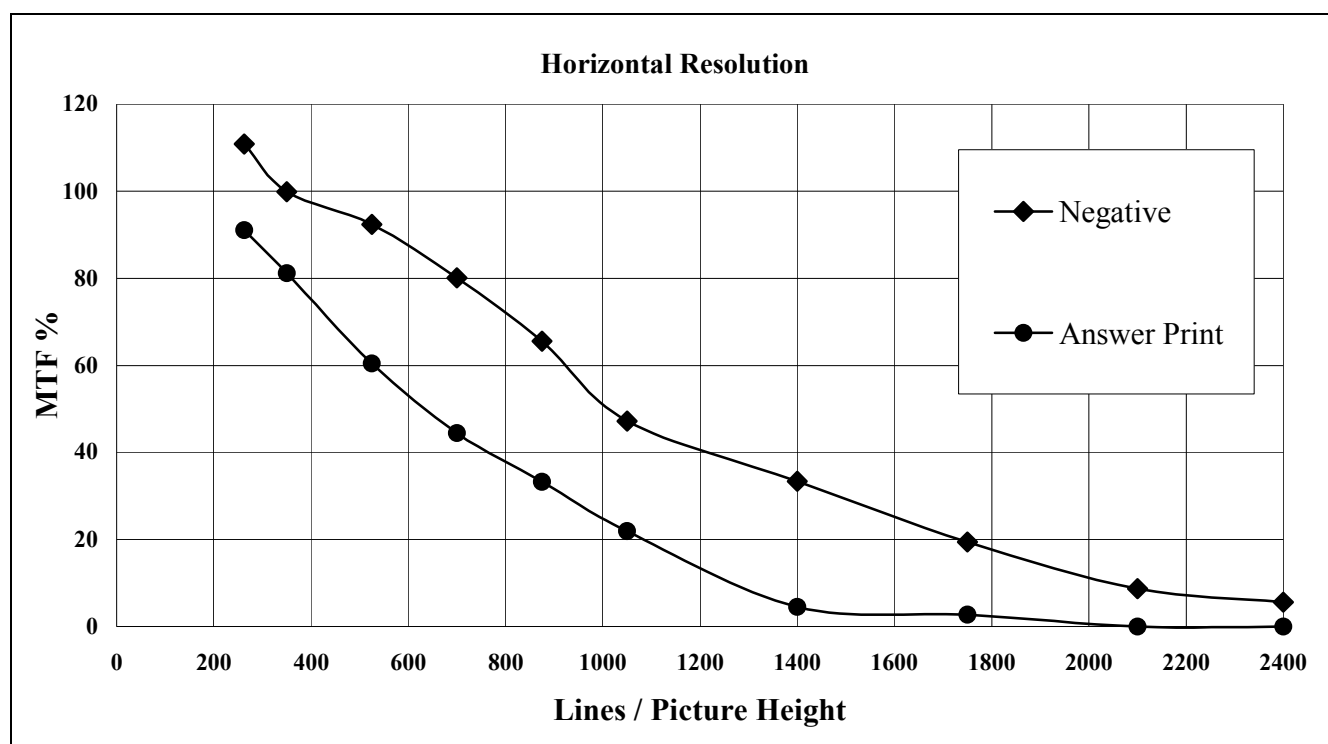


FIGURE 3

Horizontal MTF of 35 mm negative and answer print films

4.2 MTF variations from print-to-print

Several answer prints were struck from the single negative obtained from the second shooting. The answer prints were struck in different laboratories, on different film stocks, and on different types of printers.

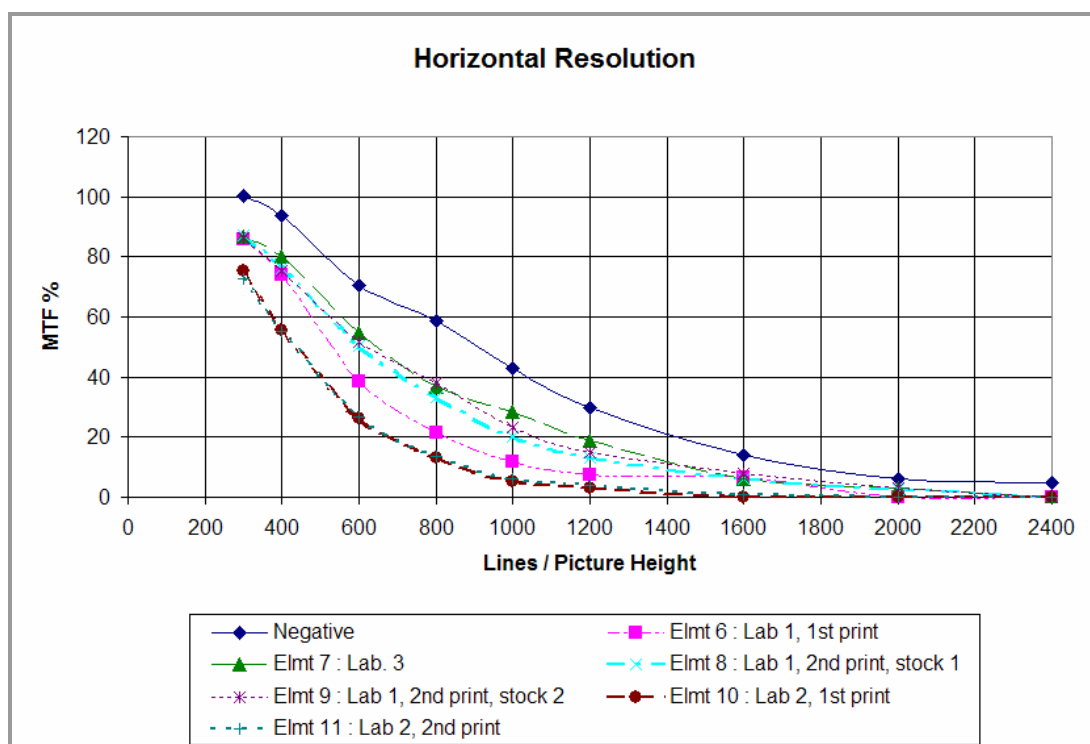
All the prints made by each laboratory were checked by that laboratory and found to be “good-for-delivery”

The MTF response curve shown in Figure 3 represents the response of the best answer print.

However a comparison of the MTF responses measured on the various answer prints shows a high variation of results. The choice of film stock had a small influence on this variation for answer prints developed at the same time in the same laboratory. This variation is shown in Figure 4.

For example, prints numbers 10 and 11 were printed in the same laboratory on the same film stock. Print number 10 was struck on a dry printer and print number 11 was struck on a wet-gate printer. Prints 8 and 9 were printed in the same laboratory, but on different film stocks.

Results of the measurements:



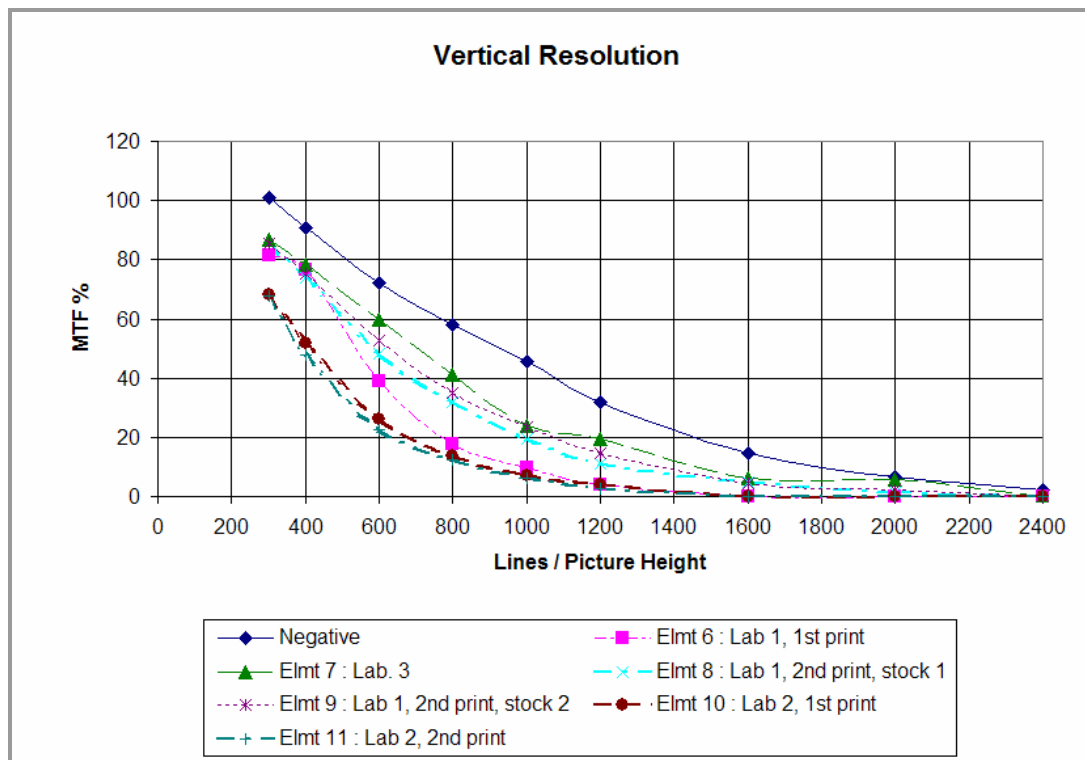


Figure 4

MTF variations from answer print to answer print

5. Subjective assessments

Each subjective assessment session used at least 7 expert assessors. All assessors were screened for normal visual acuity with or without corrective glasses.

Subjective assessment sessions were held in movie theaters equipped with state-of-the-art projection facilities. The theaters were completely darkened during the test sessions.

Assessors were seated in central seats at a viewing distance of 1.5 times picture height from the screen. The choice of this short viewing distance was due to the need for the tests to produce highly discriminating results.

Assessors were asked to score each one of the eight multiburst groups present on the projected image, identifying the highest spatial frequency burst in each multiburst group, where they were able to distinguish the bar structure. Each scoring sheet was labeled with the name of the assessor, the seat number, the date and the time at which the test session was carried out.

Each formal subjective assessment session was followed by an informal “expert viewing” session, during which the experts had an opportunity to verify the opinions expressed during the formal test, looking at the test material as long as they wanted, getting as close to the screen as they liked, and discussing among themselves to find a common agreement of the perceived quality.

Formal subjective assessment sessions were held for the first phase of the test, according to the assessment procedure described in section 4.

The assessment sessions were held in a total of 6 movie theaters located in Orlando, Florida, in Los Angeles, California, in New York, NY, in Montreal, Canada, in Paris, France, and in Milan, Italy.

The results of the test obtained in the six theaters are summarized in the tables below, separately for each theater and for release print shot with the normal (spherical) lens.

For each theater, the tables show the average number of lines per picture height that the assessors detected in each one of the eight sections of the projected test chart where multiburst groups are present. The reported numbers are the mean values of the scores cast by the assessors. Their positions on the tables correspond to the positions, identified by letters from A to H, where the related multiburst groups are located.

A		E		D
600				632
	G	653	H	
	579	F	516	
B		684		C
674				642

FIGURE 4 A

Release print resolution assessed in the Orlando movie theater

A		E		D
800				750
	G	875	H	
	550	F	525	
B		825		C
875				825

FIGURE 4B

Release print resolution assessed in the Los Angeles movie theater

A		E		D
733				667
	G	733	H	
	467	F	433	
B		700		C
667				667

FIGURE 4 C

Release print resolution assessed in the New York movie theater

A		E		D
720				700
	G	740	H	
	580	F	520	
B		720		C
680				740

FIGURE 4 D

Release print resolution assessed in the Montreal movie theater

A		E		D
700				700
	G	767	H	
	533	F	500	
B		733		C
700				600

FIGURE 4 E

Release print resolution assessed in the Paris movie theater

A		E		D
600				600
	G	640	H	
	560	F	480	
B		680		C
720				680

FIGURE 4 F

Release print resolution assessed in the Milan movie theater

A subjective assessment of the second phase of the test (Answer Print) was conducted at the Megaplex Spheretech 14 Theater, Ville Saint – Laurent, Canada. The results are shown below.

A		E		D
840				770
	G	760	H	
	740	F	630	
B		680		C
860				805

FIGURE 5

Answer print resolution assessed in the Ville Saint-Laurent movie theater

6. Conclusions

In the framework of the activity of ITU-R Study Group 6 related to Large Screen Digital Imagery (LSDI), a test was performed in order to determine the end-to-end resolution provided by 35 mm cinema film projection in typical motion picture theaters today. This can be considered to be one of the main perceptual reference performances for the cinema today.

The test evaluated the typical resolution obtained on theatrical presentation of 35mm release prints and answer prints, that is achieved in normal operation, utilizing existing state-of-the-art 35 mm cinema film equipment, film stocks, processing, printing, and projection in actual day-to-day use for feature films today.

A resolution test pattern was photographed on a 35 mm negative film stock typical of those used for the production of feature films, and 35 mm interpositive, internegative, release prints and answer prints were struck from that negative in conformity with current cinema routines.

Measurements of the MTF (Modulation Transfer Curve) on the resolution test pattern were then taken on the 35 mm negative, interpositive, internegative, release prints and answer prints.

The best 35 mm release print was also projected in six selected movie theaters in various countries, and an international panel of experts assessed the resolution of the projected images, using a well-defined formal assessment procedure.

The MTF measurements performed on the films have shown that the MTF on the negative film drops to 10% of its peak value at about 2100 lines/PH (lines per picture height). It gradually continues to drop along the film chain from negative to interpositive to internegative and to release print, and it reaches 10% of its peak value at about 1000 lines/PH when measured on the release print.

When measured on the answer print, it reaches 10 % of its peak value at about 1400 lines/PH.

The MTF measured on the 35 mm answer print film quite closely matches the one measured on the 35 mm interpositive film. This is not surprising, since a 35 mm interpositive is a positive film printed from the original 35 mm negative, as a 35 mm answer print is.

Obviously, it must be expected that the resolution measured on the 35 mm release print (or on the answer print) will suffer some reduction when the print is projected in a movie theater, due to the passage of the image through the projector mechanism and lens

Indeed, this was confirmed by the subjective assessment tests. They have shown the following.

- There was quite a spread in the resolution performance of the six selected movie theaters where the assessment tests were performed.
- There was also some spread in the resolution performance of each selected movie theater, when measured at various points of the screen.
- The highest resolution that the expert assessors could still discern in the sharpest part of the screen (not necessarily in its center) in the most performing movie theater was about 875 lines/PH.
- The average resolution in the sharpest part of their screen of the six movie theaters was about 750 lines/PH.
- The highest resolution averaged over the eight multiburst groups measured on the screens of the six selected movie theaters was about 685 lines/PH.
- A wide range of resolution values will be obtained, depending on the stocks, the laboratory, the type of printer, etc.

Note: The matters covered in this report are more fully treated in the following ITU-R documents.

6/149 9.20.01 35mm Cinema Film Resolution Test Report.

6-9/3Rev.13.5.02 35mm Cinema Film Resolution Test Report. Update of Part 4 of 6-9/3.

6-9/47 (Rev.2) 9.20.02. Revised Report on the status of the 35mm Answer Print Resolution Test

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