Improving 8mm – Type S (Super-8) Optical Sound by Design of Film and Recording System

A TRANSLATION

By KATSUJI MURAMATSU

The factors are examined that need to be improved in order to achieve a substantial improvement in the quality of 8mm – Type S (super-8) sound using the variable-area optical sound approach. As a result of the study, Fuji Fine Grain Sound Recording Film (Variable Area) Type II was developed and is being sold on a trial basis. Being of superfine grain and ultrahigh resolution, this film is intended for sound recording use exclusively with the 8mm – Type S system; its panchromatic emulsion resembles that of high-resolution microfilm, and its speed is comparable to that of Fuji Type 72412 film. Actually realizing the benefits of using such a film, however, requires that a high-performance nonslip printer such as the Peterson printer be used in the printing stage. The use of Fuji Type II film and such a printer permits a 10-dB improvement in output at 5 kHz over other conventional systems.

THE HISTORY OF technological innovations employed to improve the quality of optical sound recording systems related to 35mm and 16mm motion-picture film is long, and the sincere efforts of many earnest researchers and engineers have been devoted to the improvement of total-system sound quality. Thanks to these efforts, it appears that a technical standard system has been well established even though improvement is still possible in certain areas.

However, the 8mm – Type S (super-8)* optical sound recording system, which in principle is the same technology as the larger format film, still should be much improved (though sound quality is certainly significantly better than it was in the early development stages). For the past several years, the author and his associates have been employing primarily photographic factor-analysis toward improving the 8mm – Type S optical sound recording system. This analysis has led to the development of a sound recording film for use exclusively with the 8mm – Type S system which is thereby significantly improved. This improved film, provisionally designated the Fuji Fine Grain Sound Recording Film (Variable Area) Type II, is characterized by extremely fine grain and ultrahigh resolution properties.

This report outlines the performance characteristics of the film together with some technical considerations related to quality improvement of the 8mm – Type S optical sound recording system. It is hoped that it will help engineers and technicians working in the optical sound recording field.

1. The 8mm – Type S Optical Sound Recording System

There are two basic types of optical sound recording systems — the variable-area type and the variable-density type — using two different methods to record the waveform on the soundtrack of the film. At present in the 35mm and 16mm motion-picture field, the variable-area type predominates, with the variable-density type used very little. This is because the variable-area sound recording film provides better recording and laboratory processing quality control. With the 8mm – Type S optical sound system, it is necessary that the film be easy to treat and control and that it be stable in quality in the processing laboratory under conditions of volume production. Thus the variable-area type soundtrack approach will probably also predominate here even though there are also some disadvantages to this soundtrack standard.

It is generally agreed that the quality characteristics of sound recording and reproduction using a film optical sound system depend on all the performance factors of the electronic sound equipment involved (the recorder and reproducer); and also important are the photographic factors: the sound film, print film, exposure, and the printer and processing conditions required for forming sound images on photographic film. Therefore, to improve the 8mm – Type S sound quality, it is necessary to determine the contribution made by each of the electronic factors and photographic factors to the overall sound quality and then improve each factor according to the importance of its contribution. Thus it is not until all factors are appropriately improved that meaningful improvement in sound quality can be realized.

In principle, the 8mm – Type S system has the same technology as do 35mm and 16mm motion-picture films. However, as shown in Table I, the limitations of 8mm – Type S film are greater than those of 35mm and 16mm motion-picture films. Inevitably, in comparison with 35mm and 16mm motion-picture film, extremely high performance is required of the film and all other related photographic factors to be used with the 8mm – Type S system. These photographic requirements are considerably more strict than electronic sound system requirements.

Photographic factors which determine the quality of the optical sound system are: (1) sound film performance factors, (2) sound film exposure factors, (3) sound film processing factors, (4) color positive film properties, (5) printing exposure factors and (6) print film processing factors. Among these factors, color positive film properties and processing are designed so as to satisfy mainly the requirements of high picture image quality; therefore, these properties may not be changed to improve the quality of optical sound recording, and so improvements have to be obtained by modifying the other photographic factors.

The most obvious fact revealed by Table I is that the performance of sound recording film is most adversely affected when format size is reduced. In the case of 8mm – Type S film, the transport speed is 4 in/s (101.6 mm/s) which is less than one quarter of the speed of 35mm mo-

Table I. Format Comparisons.

	8mm – Type S	16mm	35mm
Film transport speed:	20 ft/min (6 mm)	36 ft/min (11 mm)	90 ft/min (27.4 mm)
Relative ratio:	1	1.8	4.5
Comparison of recording frequencies*	5000 Hz 2000 Hz	9000 Hz 3600 Hz	22500 Hz 9000 Hz
Scanning width			
Aperture (G)	0.64 ± 0.03 mm	1.83 ± 1.78 mm	2.13 ± 0.03 mm
Relative ratio	1	2.8	3.3
100% modulation			
Width (C)	0.51 mm	1.52 + 0.15 mm/ −0.03 mm	1.93 ± 0.03 mm
Relative ratio	1	3.0	3.8

* Compared for theoretically recordable frequencies for a given film length.

Translated from the *Journal* of the Motion Picture and Television Engineering Society of Japan, Inc., No. 248, pp. 34–44, April 1973, through the courtesy of Tatsuo Hirabayashi, General Secretary, Motion Picture and Television Engineering Society of Japan, Inc., Sankei Bldg., 1-7-2 Otemachi, Chiyoda-Ku, Tokyo 100, Japan. The author is Katsuji Muramatsu, Fuji Photo Film Co. Ltd., Product Development Center, 13-6, Minamiazabu 2-Chome, Minato-Ku, Tokyo 106, Japan.

* The 8mm – Type S designation used in this paper refers to what is commonly known as super 8.

tion-picture film; compared with 16mm motion-picture film, it is about half as fast. Differences in film transport speed directly affect the frequency characteristics that can be recorded on the film. The capability of making a perfect recording of 5,000 Hz on an 8mm – Type S soundtrack corresponds to a 35mm motion-picture film recording capacity of 22,500 Hz. In other words, when a 35mm motion-picture film capable of making a perfect recording in the upper limit frequencies (9,000 Hz) is used in an 8mm – Type S system, the maximum recordable frequency is only 2,000 Hz.

Even if one only considers recordable frequency range, it is quite obvious that the performance requirements of the smaller format film must be far greater than those for 35mm or 16mm film. Moreover, in regard to a 100% modulation width on the soundtrack (directly related to signal output, SNR and dynamic range quality), the 8mm – Type S modulation width is only 0.51 mm which is about a fourth that of 35mm soundtrack and about a third that of a 16mm soundtrack. These restrictions — unalterable "givens" in the 8mm – Type S format — make it more susceptible to increases in background noise due to film grain, dust and film surface scratches.

Because no sound recording film has been available for exclusive use with an 8mm – Type S system that at the same time could meet the stricter requirements, sound recording film designed for 35mm and 16mm motion-picture purposes was modified to be used as 16/8mm – Type S film. Inevitably this resulted in a deterioration of the sound quality.

2. Characteristics of the Sound Recording Film Developed for Use in the 8mm – Type S Format

A long and varied series of theoretical investigations, photographic experiments and practical tests, has culminated in the development of Fuji Type II film, a film with the fundamental characteristics of ultrafine grain and high resolution required for the variable-area type optical sound recording system. Since these characteristics are very similar to those of high-resolution microfilm, the new film uses approximately the same type of emulsion.

For reasons that will shortly be made evident, it was necessary to make Fuji Type II film panchromatic (unlike sound recording films derived from 16mm film stock), and this fact requires that Type II film be handled as carefully as other general-purpose motion-picture films.

Type II film incorporates an extremely thin emulsion layer less than half as thick as Type 72412 film (Fuji Fine Grain Sound Recording Film, Variable Area, Type 72412 — 16/8mm – Type S). Instead of a gray base, it uses an in-process neutralizing subemulsion antihalation layer, and this combination greatly decreases sound image blur caused by halation and irradiation. The processed film is as clear as any conventional positive film. The major properties of the Type II film are described below.

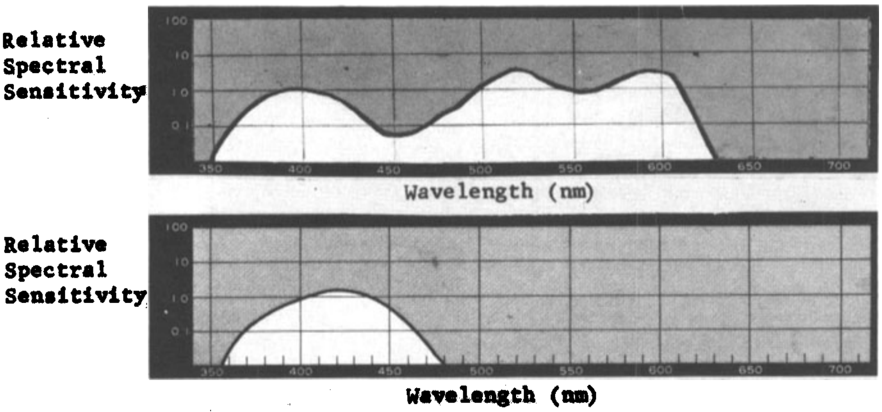

Fig. 1. Spectral sensitivity curves: tungsten light source (2854 K); Type II film (above) Type 72412 film (below).

2.1. Spectral Sensitivity

One of the ways in which Type II film differs from conventional sound recording film is in its spectral sensitivity. Conventional sound recording films such as Type 72412 film are ultraviolet and blue-sensitive. Type II film, however, has been made panchromatic; it is even more sensitive at 525 nm and 600 nm than it is at 400 nm (Fig. 1). This has been necessary because if it were sensitive only to ultraviolet and blue light and yet required to have ultrafine grain, high resolution and high gamma, it would lack the necessary speed. Making Fuji Type II film panchromatic permits a substantial increase in speed. It is thus undesirable in terms of light sensitivity to expose this film to ultraviolet rays as in ordinary optical sound recording. This is also undesirable because Type II film has an extremely thin emulsion layer and exposure to UV generally works best with thick emulsions.

Since conventional recorders are designed for use with blue-sensitive film, they have no provision to correct for chromatic aberration in the recording optical system. Although it was feared that exposure of Type II film in such ordinary recorders might blur the sound image and thus reduce quality because of this optical system chromatic aberration, it was found that substantial problems were avoidable simply by correcting for deviation in the focal plane.

2.2. Speed

When Type II film is exposed under the white light of an ordinary sensitometer and processed in Fuji Positive Developer FD-31, almost the same speed is attained as with Type 72412 film. When the films are exposed under the white light of a Westrex recorder and processed under commercial laboratory conditions, relationships may be plotted between the exciter lamp current and the soundtrack density for the two films as shown in Fig. 2; it is evident that the speed of Type II film under such conditions is slightly higher than Type 72412 film.

Figure 3 shows the results of exposing the film under both white light and ultraviolet rays in an RCA PM-80A recorder and then processing it under commercial laboratory conditions. When sufficient light is provided in such recording, ultraviolet exposure also becomes possible.

2.3. Characteristic Curves

For comparison purposes, Fig. 4 shows the characteristic curves and time gamma curves for both Type II and Type 72412 films processed as specified in Fuji Positive Developer FD-31. Note that Type II film possesses the fundamental characteristics required of sound recording film of the variable-area type: high gamma and a characteristic curve with a sharp cutoff.

2.4. Processing

By using Fuji Positive Developer FD-31 as specified, required contrast can be obtained by treating the film for 4 to 6 min at 68°F (20°C). Also good results are obtained through the use of positive developers employed at ordinary commercial laboratories. For safelight illumination, Fuji Safelight Glass Filter No. 2B (red) cannot be used: the film must be handled in total darkness or under a safelight using Fuji Safelight Glass Filter No. 4 (dark green). Special precautions must therefore be taken when the film is processed in a machine of the conventional type designed for positive film.

2.5. Static Sound Recording Characteristics

When investigating possible approaches to improving the overall audio-dynamic characteristics of electronic sound equipment and photographic processes, it is very useful to obtain static sound recording characteristics which indicate the actual sound performance of

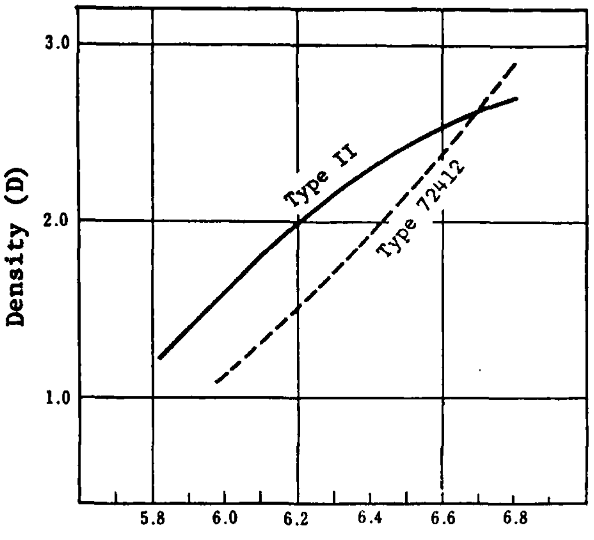

Fig. 2. Relationship between the Westrex recorder (white light exposure) lamp current and the density of the films.

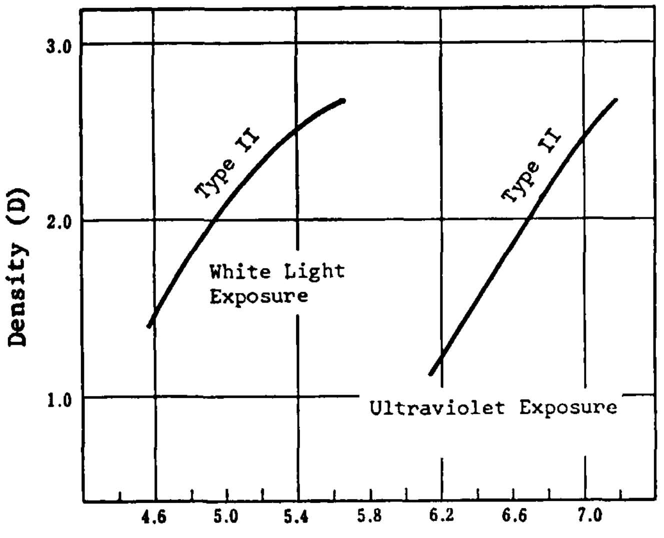

Fig. 3. Relationship between the RCA PM-80A recorder lamp current and the density of the films.

the film itself. This performance, in turn, becomes a major factor in determining the ultimate quality achieved in the 8mm – Type S optical sound recording system. The static sound recording characteristics of Type II film are shown in Fig. 5. These characteristic values are for the film itself; recorder and reproducer factors are not included.

Measurement: In order to obtain characteristic values, two kinds of test charts are necessary — one for cross-modulation testing to determine the value of an optimum cancellation density for the particular negative-positive film combination to be used (Fig. 6) and another for measuring frequency response and SNR (Fig. 7). A geometrical cross-modulation test chart was created from the cross modulation of 4 kHz and 400 Hz, with the sine wave pattern area being limited to an 80% modulation within the width of the 8mm – Type S soundtrack. Likewise, a geometrical frequency response test chart was created from sine wave patterns made by modulating 400 Hz, 1 kHz, 3 kHz, 4 kHz and 5 kHz, respectively, to an 80% modulation with a 50% nonmodulated track.

The test charts were prepared by taking reduction photographs of originals prepared in magnification through the use of an ultra-micro camera system developed by the Fuji Film Research Laboratory, so that the original magnification charts were reduced to the size of the waveforms on an 8mm – Type S soundtrack.

To prepare test samples, we used the cross modulation test chart and frequency response test chart already described. We exposed the sound recording film to white light from a tungsten lamp at about 2800 K. For the printing of color positive film, a tungsten lamp was used together with a Wratten No. 2B filter plus a No. 12 filter. Only two film emulsion layers, the ones sensitive to red and green, were exposed.

A vacuum contact printer by the Dainippon Screen Co. was used to prevent the image blur caused by poor surface-to-surface contact. The wet print method was adopted in order to eliminate the Newton rings that appear when contact is nearly perfect.

The Type II and Type 72412 films used were developed with continuous agitation for 5 min at 68°F (20°C) in Fuji Positive Developer FD-31.

The print film, Fujicolor Positive Film Type 8822 (16/8mm – Type S), was processed according to procedures specified for Fujicolor Positive Film.

To obtain optimum cancellation density values (negative-to-positive density values that would minimize cross-modulation distortion), samples were proposed varying in negative density from 1.5 to 3.0 and in positive density from 1.3 to 2.3. By using different combinations of these samples, the cross-modulation distortion output level for each combination of samples was calculated from the change in average transmittance when the wave sample was scanned with a microdensitometer (scanning aperture slit width 2.5 μ).

Transmittance ratio changes in peak-to-peak values were obtained by microdensitometer waveform scanning of the frequency response test chart printed at the optimum cancellation density value obtained from the cross-modulation chart test samples. Microdensitometer scanning of a sample printed at optimum cancellation density from the frequency response test chart having a 50% unmodulated track and an 80% modulated 1 kHz sine wave gave peak-to-peak

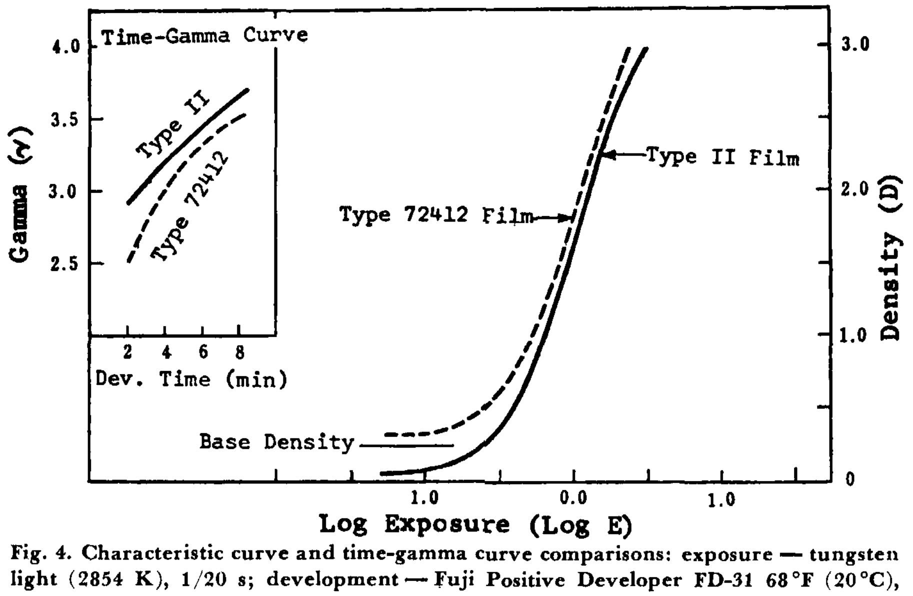

Fig. 4. Characteristic curve and time-gamma curve comparisons: exposure — tungsten light (2854 K), 1/20 s; development — Fuji Positive Developer FD-31 68°F (20°C), 5 min.

(a) Optimum Cancellation Density Values for Negative and Positive Film

Sound Recording Film	Sound Track Density*	
	Negative	Print**
Type II Film	2.60	1.80
Type 72412 Film	2.10	1.80

(b) Frequency Response and Signal-to-Noise Ratio

Sound Recording Film	Frequency Response (5kHz)	Signal-to-Noise Ratio (1kHz, 80% Modulation)
Type II Film	-2.5dB	47dB
Type 72412 Film	-7.8dB	42dB

*Macbeth Densitometer TD-404, Status A-58 Filter

***Fujicolor Positive Film Type 8822 (16/8mm - Type S)*

(c) Frequency Response

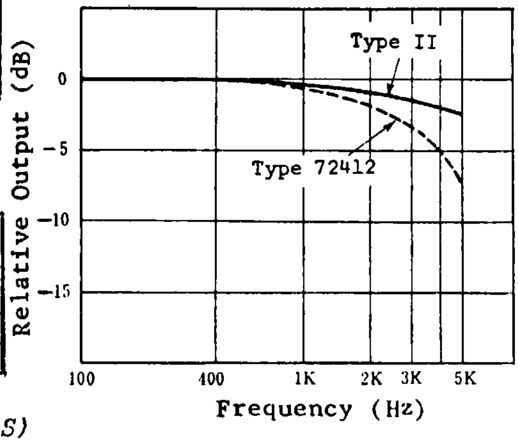

Fig. 5. Comparison of static sound characteristics on the sound recording film.

values for the signal amplitude relative to the noise level.

Comparison of Characteristics: With respect to the optimum cancellation density value for minimizing cross-modulation distortion at the same print density, Type II film is shifted to a higher negative density than Type 72412 film. Because Type II film has higher performance than Type 72412 film and accordingly causes less blur in the sound image, cancellation is made at a higher density in the case of Type II film even though the prints used have identical densities. Moreover, regarding the static frequency response, the output of Type II film is improved by about 5 dB at 5 kHz over Type 72412 film. In addition, the SNR of Type II film is improved by about 5 dB because of the extremely fine grain emulsion.

The above tests confirmed that substantial improvements had been made in the static sound characteristics of Type II film. The next step taken was to measure the dynamic sound characteristics of the film as used in actual practice.

2.6. Dynamic Characteristics of the 8mm – Type S Optical Sound Recording System

As examples of the measurements made, Figs. 8 and 9 show the results obtained in cross-modulation tests in which a Westrex recorder was used to record with the 8mm – Type S system. At the same print density, the optimum negative density value for Type II film was higher by 0.2 to 0.3 than Type 72412 film and the optimum area of cancellation density of Type II film was about two times broader than that of Type 72412 film. The photographic process latitudes of Type II film are thus broader than those of Type 72412 film. For laboratory processing of Type II film, these results are highly desirable. The total (dynamic) frequency response of Type II film is equivalent to that of Type 72412 film in the lower frequencies up to 2 kHz; however at 5 kHz the output of Type II film is improved by about 6 dB over Type 72412 film. With respect to the dynamic sound characteristics of Type II film, almost the same results have been

Fig. 6. Cross-modulation test chart: 4-kHz/400 Hz, 80% modulated.

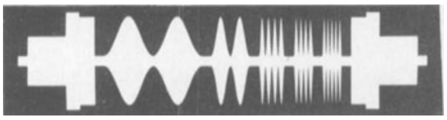

Fig. 7. Frequency response test chart: 400-Hz, 1-kHz, 3-kHz, 4-kHz and 5-kHz, modulated 80% with 50% unmodulated track.

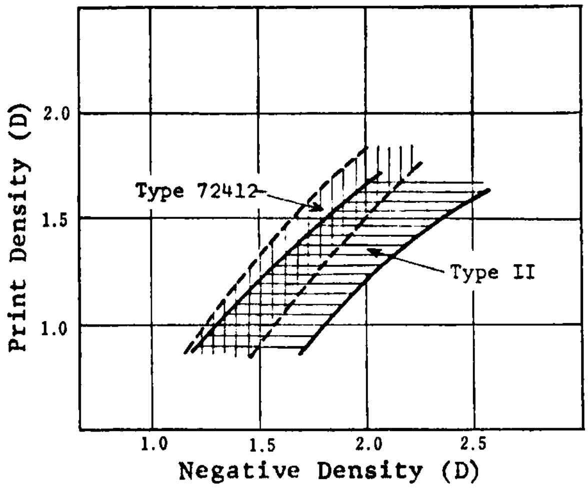

Fig. 8. Comparison of optimum cancellation density regions for print film – Fujicolor Positive Film Type 8822 (16/8mm – Type S).

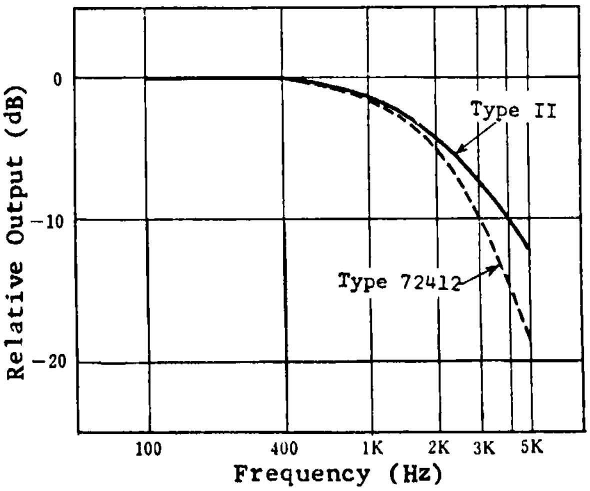

Fig. 9. Comparison of total frequency response on Westrex recorder print film – Fujicolor Positive Film Type 8822 (16/8mm – Type S).

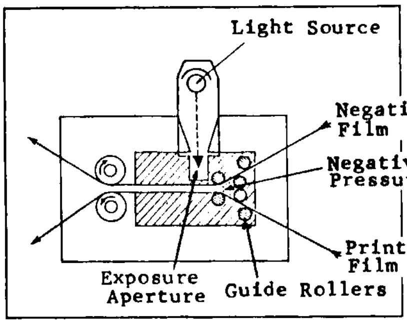

Fig. 10. Principle of the Extek printer.

derived as those attained under static recording test conditions.

3. The Influence of Printer Image Transfer Characteristics

It is known that printer characteristics have a great effect on the quality of optical sound recording systems. This effect becomes even more significant as the film format is reduced in size.

If a 35mm printer has performance characteristics allowing for faithful image transfer of up to about 20 lines/mm in terms of resolution, this performance level is acceptable for all practical purposes because printing in the upper limit frequency (9 kHz) on 35mm film is possible without any deterioration in sound quality. However, in the case of 8mm - Type S film, a printer meeting the 20-lines/mm standard cannot record beyond 2 kHz on print film. The development of 8mm - Type S sound recording film has made it possible to record up to 6 kHz (the upper limit frequency for 8mm - Type S film) on negative film without any difficulty. However in order to transfer this high-quality negative image onto the print film, a high-resolution high-performance printer that can unfailingly transfer image resolutions of more than 50 lines/mm is required.

Unfortunately, it has been confirmed that the output levels of most printers actually used at commercial laboratories do not meet this requirement; the output undergoes considerable change when the resolution reaches about 30 lines/mm, due to slip and blur caused by imperfect film contact. Even though a high-performance film may be used for the sound recording negative, its advantages will be largely negated if a conventional printer is used.

Faced with this problem, we decided to investigate whether image transfer characteristics could be improved through the use of a high performance printer. For the purposes of this investigation an Extek nonslip printer, originally designed for making high-speed contact prints on micro-positive film from micro-negative film, was modified for use with 8mm - Type S film. This modified printer is designed to maintain good contact between the negative and the positive films by use of a vacuum system just in front of the exposure aperture so that the pressure between the negative film and the positive film becomes negative with respect to the atmosphere. The system is illustrated in Fig. 10.

Using Type II film as the sound negative film, test prints were made on Fujicolor Positive Film Type 8822 with the modified Extek printer and with an ordinary continuous printer such as is found in commercial laboratories. The results are shown in Figs. 11 and 12. Figure 11 shows the optimum cancellation density area which was obtained through the cross-modulation test method. As for the sound negative density value for a given print density, the modified Extek printer allowed for a lower negative density of about 0.3. This indicates that poor contact inherent in ordinary continuous printers where it produces image blur was greatly reduced. Furthermore, since film slip and image blur caused by poor contact were eliminated, the cancellation density area was broadened by about 20% and the cross-modulation distortion was lowered. This permitted the frequency response characteristics to be elevated by about 4 dB at 5 kHz.

Figure 13 shows the continuous output levels of recordings made on the two printers at frequency levels of from 1 to 5 kHz as derived from a high-speed level-recorder. At frequencies higher than 3 kHz, there was considerable level variation with ordinary continuous printers. On the other hand, prints made in the modified Extek printer were stable and results were of high quality up to 5 kHz. A microscopic examination of the sound image on the printed film also shows these differences clearly. In the case of prints made on the ordinary printer, blurred sound images (Fig. 14(a)) as well as sharp sound images (Fig. 14(b)) can be seen along with the kind of waveform that results from each. Note that the output was partially lost even in the nonslip portion and almost entirely lost and obscured when the film slipped. In the case of the modified Extek printer, the sound negative image was routinely transferred in sharp relief onto the print in a very stable manner, and thus its output level is greater (Fig. 14(c)).

Since the performance of the printer has such an effect on sound quality, various studies were made to determine the best printers to use with 8mm - Type S. The results of these studies showed that the Peterson printer, designed exclusively for sound recording on 8mm - Type S film, is equivalent in characteristics to the modified Extek printer (Fig. 13). On being introduced to commercial laboratories, this printer has contributed greatly to quality improvements of the 8mm - Type S optical sound recording system.

By selecting a film (Type II film) and a printer (the Peterson printer), both designed for exclusive use with the 8mm - Type S system, it has become possible for sound output to be raised by 10 dB at a frequency of 5 kHz over the conventional combination of film and printer. Furthermore, because of increased out-

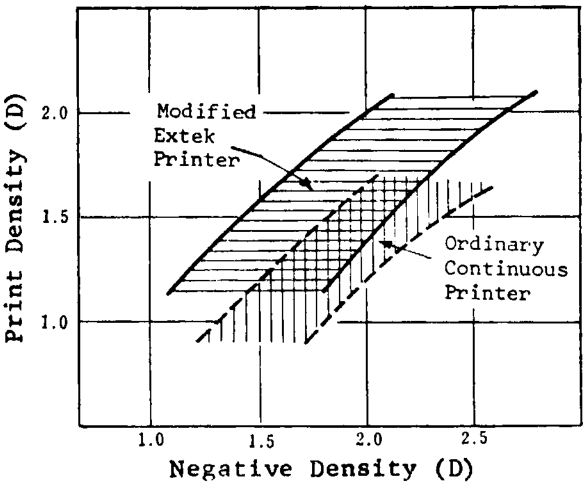

Fig. 11. Comparison of optimum cancellation density regions.

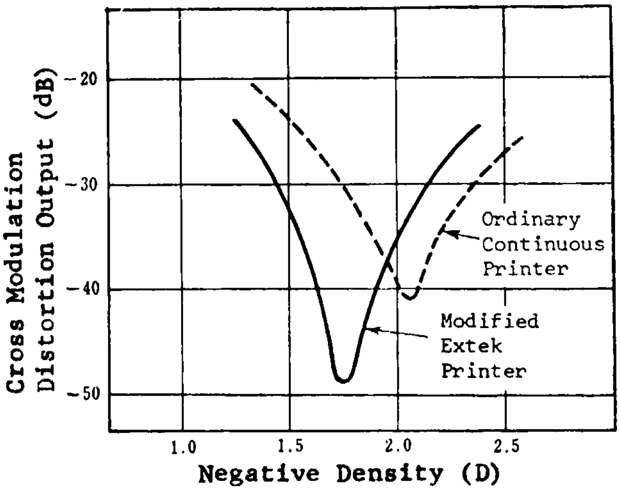

Fig. 12. Comparison of cross-modulation distortion output; print density, 1.50.

put stability, a high degree of sound quality improvement was confirmed through the use of an actual program source.

4. 8mm – Type S Cross-Modulation Testing, Considerations and Formulations

Cross-modulation testing is the most suitable method for determining optimum conditions for the variable-area optical sound recording system under practical use. It has been advocated that the high-frequency component of the cross-modulated frequency to be used in the cross-modulation test be in the upper limit frequencies under practical recording conditions, and RCA has recommended the use of 9 kHz for 35mm recording. As a matter of fact, 6- to 7-kHz frequencies are used more often in practice, and the use of 4-kHz frequencies for 16mm sound recording is standardized by ANSI.

So far the frequency range for recorders used in the 8mm – Type S system has been limited to a range of from 100 Hz to 6 kHz (Fig. 15). Moreover, the upper frequency limits compatible with stable reproduction output are limited to less than 4 kHz because of film-printer performance limitations. Also, due to measurement equipment restrictions, cross-modulation test conditions designed for 16mm film have been adopted for 8mm – Type S film as well. It has been confirmed that the acoustic characteristics available within cancellation density range limitations under 16mm test conditions apply also in practical use. However, since the 8mm – Type S conditions have been improved, using a special film and a special printer, to be capable of obtaining these frequency ranges with stable output, optimum cross-modulation conditions for this system were formulated.

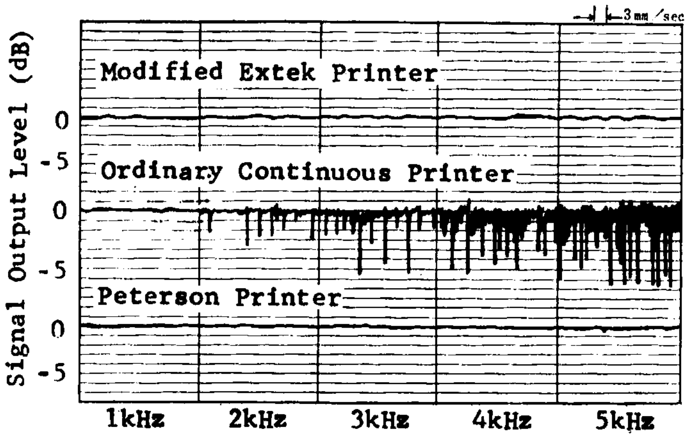

Fig. 13. Continuous recording output levels for various printers.

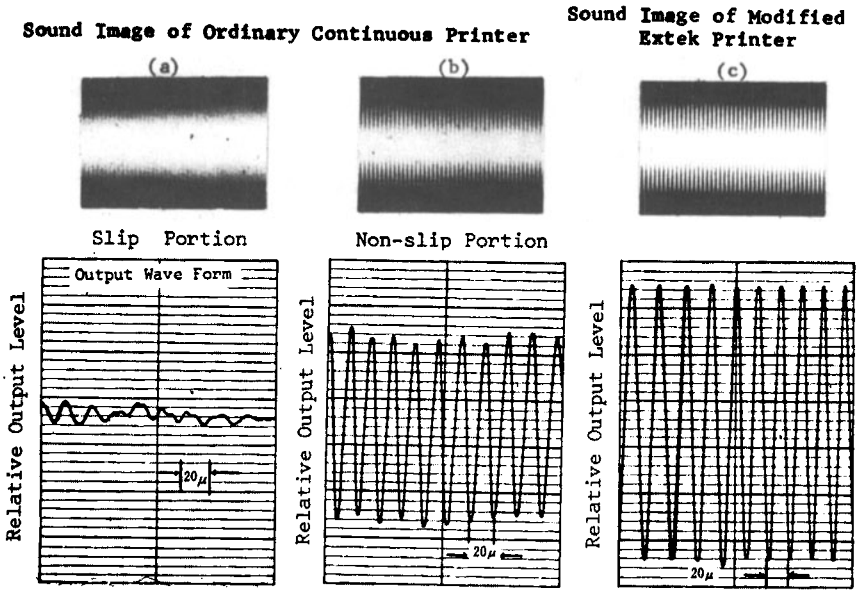

Fig. 14. 5-kHz signal recorded on print film.

4.1. Experimental Conditions

With the lower frequency component of the cross-modulation wave kept at a 400-Hz constant, cross-modulation output distortion was obtained when the higher frequency component was varied in the range from 2 kHz to 6 kHz. Above and beyond this, various electronic and acoustical characteristics were measured. To make the results strictly comparable, the audio quality was evaluated using an actual program source. From the results of these tests in combination, suitable test conditions for the 8mm – Type S system were obtained. These experiments were conducted utilizing unaltered the same commercial laboratory procedures that are used generally for the production of 8mm – Type S sound prints. Table II gives the conditions and equipment used in this experiment.

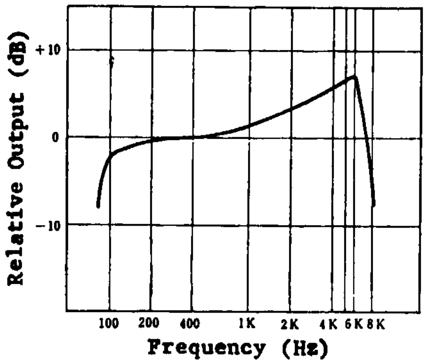

Fig. 15. Recording frequency characteristics of the RCA PM-80A recorder.

4.2. Determination of Cross-Modulation Test Conditions

By varying the recorder's exciter lamp current, 11 exposure steps ranging in density from 1.0 to 2.75 were made of a cross-modulation waveform for the measurement of cross-modulation distortion and also of a sinewave for the measurement of reproduction output and total harmonic distortion, and from these exposures, the test negatives were prepared. Then test samples were made for measurement by printing these prepared

Table II. Soundtrack Test Sample Preparation Equipment and Experiment Conditions.

Test Generator: Toa Denshi Cross Modulation Generator
Test Frequencies: 80% Modulated Sinewave at Frequencies of 400 Hz, 2 kHz, 3 kHz, 4 kHz, 5 kHz and 6 kHz
80% Cross Modulated Wave at Frequencies of 2 kHz/400 Hz, 3 kHz/400 Hz, 4 kHz/400 Hz, 5 kHz/400 Hz and 6 kHz/400 Hz
Recorder: RCA PM-80A Recorder
Sound Film: Type II Film
Sound Film Processing: Standard processing for sound film (Tokyo Television Center Co.)
Printer: Peterson 8mm – Type S Sound Printer (Fujicolor Service Co.)
Print Film: Fujicolor Positive Film Type 8822 (16/8mm – Type S)
Print Film Layers Used: green and red layers
Print Film Processing: standard processing for Fujicolor Positive Film

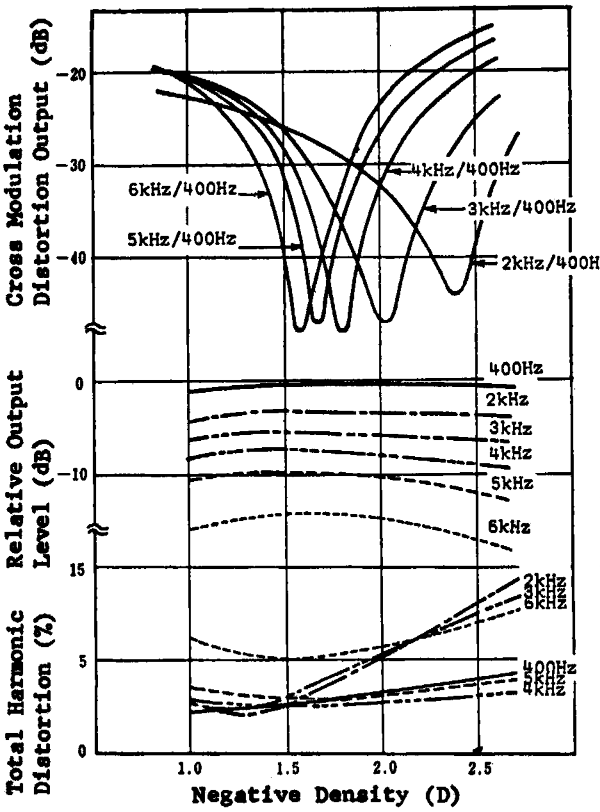

Fig. 16. Cross-modulation distortion output, signal output and distortion level as related to negative density; print density, 1.67.

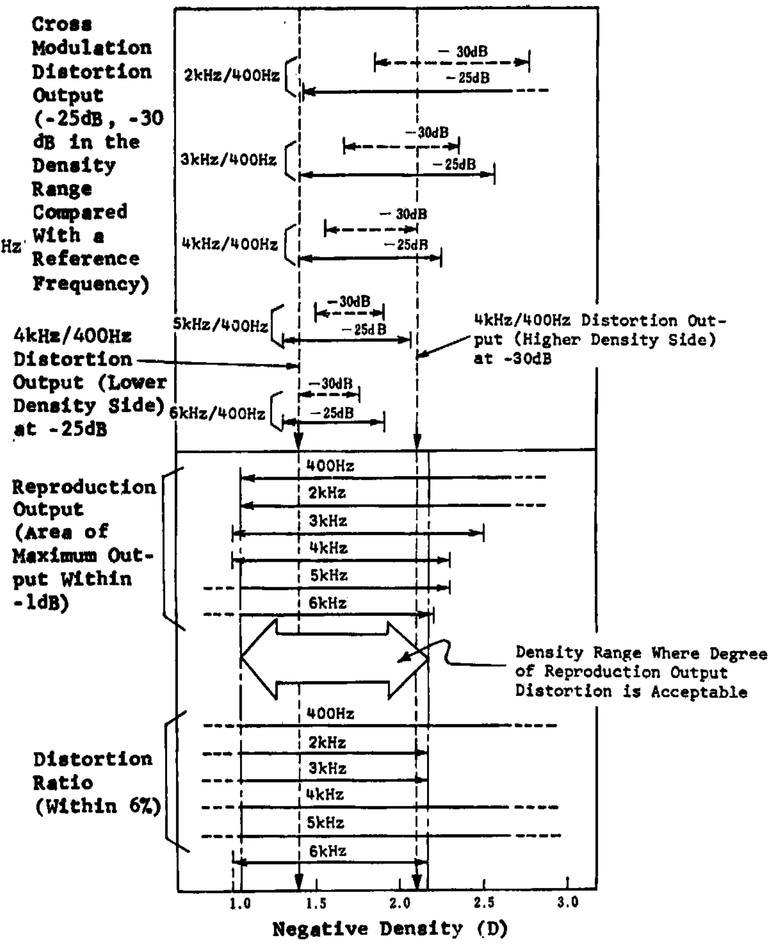

Fig. 17. Cross-modulation cancellation density range, maximum signal output and minimum total harmonic distortion as related to negative density range; print density, 1.67.

negatives in five ranks of density from 1.0 to 2.45, on print films.

Figure 16 shows the relationships between the cross-modulation distortion output for each modulation wave, the signal reproduction output and the total harmonic distortion for each sinewave having a print density of 1.67 in relation to the variable negative density. Figure 17, obtained from Fig. 16, illustrates the negative density range in which the cross-modulation distortion output for each modulated wave becomes less than −30 dB and −25 dB, respectively, in comparison with a reference frequency. Also Fig. 17 shows the negative density range for the maximum reproduction output level of each signal and the negative density range for the minimum degree of total harmonic distortion (not more than 6%).

As can be seen from Fig. 17, the negative density range, in which the cross-modulation distortion output is minimized, is shifted to a lower density when the higher frequency portion of the cross-modulation wave is increased in frequency.

The higher the modulated frequency becomes the more the waveform's peaks and valleys become too steep and result in increased blur. At the time of printing, in order to cancel this blur that has been formed on the negative, a higher print density must be used with every increase in frequency of the higher frequency portion of the cross-modulation wave. On the other hand, in order to make a print having uniform density, the higher the high-frequency wave becomes in the cross-modulation wave, the lower the negative density must become in order to cancel out blur. It is for this reason that the negative density is shifted so as to minimize output distortion related to cross modulation.

As in Fig. 17, the density region shown as the most appropriate for an output distortion of less than −30 dB under previous test conditions adopting a 4-kHz modulated wave, only the 4-kHz cross-modulation wave generates less than −30 dB of output distortion but cross-modulation waves with higher components of 2 kHz, 3 kHz and 5 kHz generate −25 dB of output distortion while the 6-kHz cross-modulation wave generates cross-modulation distortion up to −20 dB.

However, because it is empirically recognized that sound quality within the density range delineated by previous test conditions is acceptable for practical purposes, it follows that these output distortion levels are permissible under practical use conditions. It is therefore anticipated that even if the output distortion generated by the 4-kHz cross-modulation wave was to increase to −25 dB (as with the output distortion caused by the other cross-modulation waves), such an increase would be acceptable. Therefore optimum recording conditions are determined within a density range where the cross-modulation output distortion of each cross-modulated wave ranging from 2 kHz to 5 kHz is less than −25 dB.

Thus test conditions to satisfy these requirements can be created by setting up a density region where cross-modulation output distortion is less than −25 dB at the lower density limits and less than −30 dB at the higher density limits for negative film using a 4-kHz modulated wave. In this density range both multi-frequency output reproduction and total harmonic distortion are maintained within satisfactory limits. Similar results are observed with other print density samples.

In Fig. 18, the cancellation density region obtained by the previous method is compared with that obtained by the present test method. Under the present test method and conditions, a low negative density range where sound quality had thus far been judged to be low due to the previous stringent test conditions, is now included as part of the optimum recording conditions (the shaded portion of

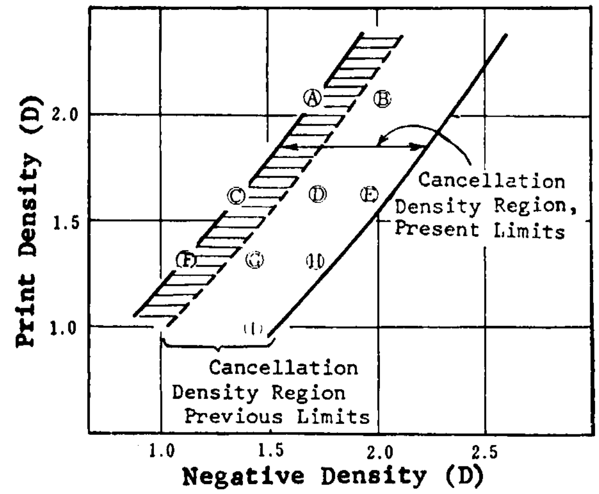

Fig. 18. Comparison of optimum cancellation density regions under previous and present test limits.

Fig. 18) and this expands the optimum density range approximately 1.4 times. From the point of view of laboratory processing this is very advantageous.

Samples for measuring electronic sound characteristics were prepared which had such negative and print densities as to remain within the cancellation density area obtained under present test conditions as shown in A to I of Fig. 18, and recording samples of actual program sources for auditory testing were prepared under identical density conditions and their various characteristics were evaluated.

Samples having a print density of less than 1.30 produced SNR deterioration caused by the lowering of the reproduction output and an increase in the noise level. However, all samples having a print density of more than 1.60 showed good frequency response and reproduction output while SNR and total harmonic distortion were within high quality limits. Thus it was confirmed that no problems arise under practical auditory testing in relation to the wider cancellation density region attained under present test conditions.

5. Conclusions

A factor-analysis of various photographic processes was conducted mainly so that the quality of the 8mm – Type S optical sound recording system could be improved through the use of a special recording film exclusively designed for that system in conjunction with a high-performance printer. Thus the cross-modulation test conditions suitable for the 8mm – Type S system have been established. These newly developed techniques are now in use at commercial laboratories for the preparation of many types of 8mm – Type S sound prints.

Fuji Fine Grain Sound Recording Film (Variable Area) Type II is being sold on a trial basis. Sound image recording characteristics are of prime importance, however, and panchromatic color sensitivity therefore became a requirement of the film. This must be considered an inconvenience to customers because unlike conventional sound recording film, this new film requires special precautions in handling. To overcome this problem, further studies are to be made relating to emulsion improvement to develop a film that will not need special handling.

Acknowledgments: The author wishes to express his thanks and appreciation to Saburo Uchida of the Tokyo Television Center Company and the engineers of the Sony PCL Company and the Fujicolor Service Company for their excellent and generous technical guidance and assistance in developing this film and in conducting various experiments.