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Improvement of image quality on mammographic screen-film system by extended-cycle process

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Summary

Extended-cycle process is the term used for a processor in which the processing time has been prolonged usually to approximate 210 seconds. It has been known that the extended-cycle process of some single-emulsion films as used for mammography may enhance film contrast and increase film speed. So the speed was increased in lower speed and higher resolution system than conventional systems by means of using the extended-cycle process in this paper. We investigated how much the resolution of the system was kept. A single screen-single emulsion combination, Konica M-100/CM-H was employed as a low speed and high resolution system. This film after exposure was processed in the different combinations of developing temperatures, 30, 32 and 34℃, and processing time of 210 seconds. On the other hand, Konica M-200/CM-H was employed as a high speed system. This film was processed in the standard-cycle processing (34℃, 90 seconds). Those systems were compared on contrast, speed, screen-film blur and noise by a characteristic curve, MTF (modulation transfer function) and WS (wiener spectrum). Furthermore, the RMI 165 phantom was used to evaluate visibility of mammographic details of these systems.

As a result, in the extended-cycle process at the developing temperatures of 32 or 34℃ and processing time of 210 seconds for M-100/CM-H, it was possible to increase the speed as much as the higher speed system, M-200/CM-H. Then the contrast, the MTF and the visibility were also improved as compared to the higher speed system. Furthermore patient dose could be reduced at the developing temperature of 34℃ and processing time of 210 seconds in M-100/CM-H.

Key words: image quality, mammography, single screen-single emulsion film system, high-resolution screen, extended-cycle process

Introduction

Today mammography is performed with screen-film combinations that have much improved imaging characteristics and are designed specifically for mammography. Films used in mammography are single emulsion when used in combination with a single back screen[1].

In same situation the x-ray unit may be the major cause of image blur resulting from motion blur due to long exposure times, or geometric blur due to focal spot size and magnification. In these situations the higher speed screen-film combination may produce mammo-

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gram with less overall image blur because shorter exposure times and/or a smaller focal spot size can be selected than is possible with lower speed high-resolution combination.

In the situation that motion and geometric blur are taken no account, the lower speed high-resolution screen-film combination may produce mammogram with less overall image blur than higher speed combination. So, if the speed could be increased without using higher speed film or screen in the lower speed high resolution combination, the high resolution image shall be produced by the system.

It has been known that the extended-cycle process of some single-emulsion films as used for mammography may enhance the film contrast and increase the film speed. Extended-cycle process is the term used for a processor in which the processing time has been prolonged usually to approximate 210 seconds, which is *longer than manufacture's recommendation*[1)-5)].

In this study the single-screen, single-emulsion film combination, Konica M-100/CM-H was employed as lower speed, higher resolution system. The image quality and visibility of the system in the extended-cycle process were evaluated on the basic of that of higher speed system M-200/CM-H in the standard-cycle process.

Usefulness of the extended-cycle process was investigated in order to contribute to improvement of image quality and dose reduction for M-100/CM-H.

Materials

Processor : Konica KX-170B
(Transport speed: variable, Processing time: 45-210 seconds.)
Densitometer : Konica PDA-15
Microdensitometer : Konica PDM-5B
Screen/Film : Konica M-100, M-200/CM-H
Mammographic unit : Toshiba Model MGU-01 (Mo target/Mo filter)
Dose meter : Radcal Model 1015 (**Probe :** Model 10x5-6M)
Half value layer kit : RMI 115A
Test chart : Kyokko type 9
(Spatial frequencies: 0.05, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 6.0, 8.0, 10.0 cycles/mm, Size: 10× 3.8 cm^2, Lead thickness: 0.04 mm)
Test object : RMI 165 phantom
Developer/Fixer : Konica XD-90·C/XF-SR

Methods

The x-ray exposures were made at 28 kV (HVL: 0.31 mmAl). The films were processed at the processing time of 210 seconds and the developing temperature of 30, 32, 34℃ in the extended-cycle process. The standard cycle was 90 seconds at the developing temperature of 34℃. The sensitometric strips for the characteristic curve, the test pattern images of the test chart, the noise samples and the test object images of RMI 165 phantom were made as follows.

1. Characteristic curve

The sensitometric strips were made by the intensity-scale sensitometry[6)]. The characteristic curves were compensated for air attenuation and smoothed with a polynomial approximation by least squares. Gradient curves were obtained from the smoothed curve by differential.

2. MTF

The square wave response function (SWRF) method[7)] with the test pattern (Kyokko type 9) was employed. The SWRF method is based on measuring image contrast at each frequency of a square-wave test pattern. The MTF was calculated from measured SWRF using Coltman's equation[8)].

3. WS

A film noise sample, exposed to a diffuse density of 1.0±0.02, was scanned on the microdensitometer. The scanning slit was 1 mm length and 10μm width. From the sampled 400,000 densities, wiener spectral values were calculated by a fast Fourier transform[6].

4. Test object images

RMI 165 phantom was used for the test object images and each image was evaluated by three radiologists and ten radiological technologists with the method of paired comparisons[9,10] about masses, fibers and specks. The RMI 165 phantom simulates the attenuation and image detail of a 50% adipose, 50% glandular, 5 cm compressed breast. The phantom produces radiographic images that are very similar to a true mammogram.

The masses were made by using thin vinyl chloride sheets and specks were glass beads with the radius of 100-150μm. The sheets and glass beads as focuses were inserted into the phantom.

Results

1. Characteristic curve

The characteristic curves in the standard- and extended-cycle processes were shown in Fig. 1. Gradient versus optical density curves taken from the data in the characteristic curves was shown in Fig. 2. Fog densities and average gradients obtained from the characteristic curves were shown in Table 1. The contrast in M-100/CM-H, 34℃—210 seconds combination increased obviously and the average gradient increased about 20% as compared to it in M-200/CM-H, 34℃—90 seconds combination with hardly increasing fog densities as shown in Table 1. The maximum gradient was also higher and the density of maximum gradient was higher as shown in Fig. 2.

2. MTF

MTFs in the standard- and extended-cycle processes were shown in Fig. 3. MTF value at

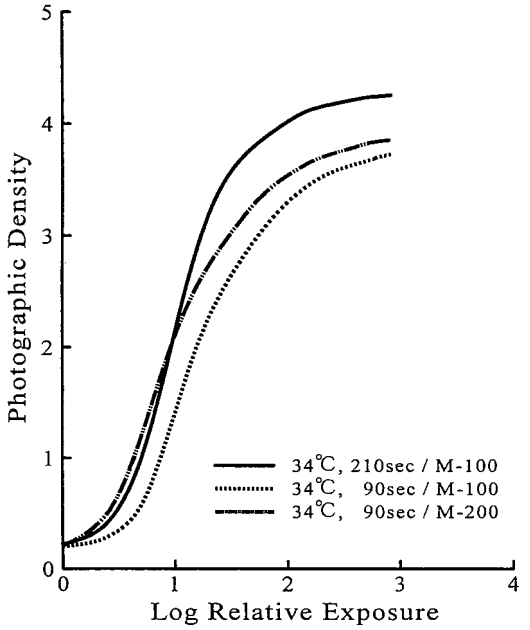


Fig. 1 The characteristic curves of M-100/CM-H and M-200/CM-H in the standard-or extended-cycle processes

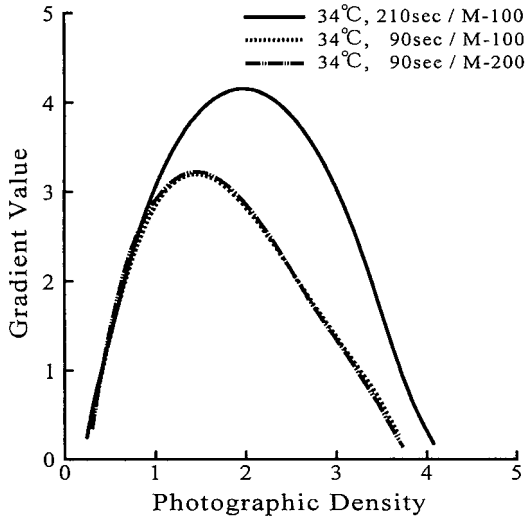


Fig. 2 Gradient versus optical density curves of M-100/CM-H and M-200/CM-H in the standard-or extended-cycle processes

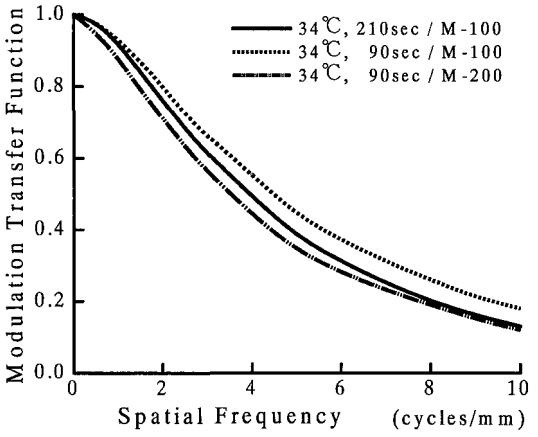


Fig. 3 MTFs of M-100/CM-H and M-200/CM-H in the standard-or extended-cycle processes

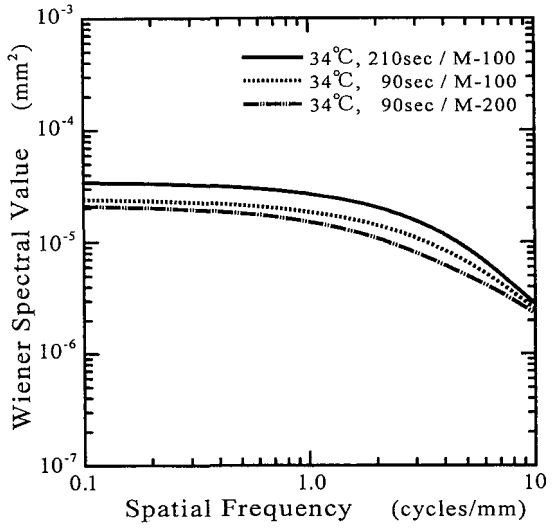


Fig. 4 WSs of M-100/CM-H and M-200/CM-H in the standard-or extended-cycle processes

2.5 cycles/mm in M-100/CM-H, 34℃−210 seconds combination increased about 8% as compared to it in M-200/CM-H, 34℃−90 seconds combination as shown in Table 1. However the value decreased as compared to it in M-100/CM-H, 34℃−90 seconds combination.

3. WS

WS curves in the standard- and extended-cycle processes were shown in Fig. 4. The WS value in M-100/CM-H, 34℃−210 seconds combination was higher due to the increased quantum mottle with increasing speed and contrast as compared to it in M-200/CM-H, 34℃−90 seconds combination. WSs at 1.0 cycle/mm were shown in Table 1.

Table 1 Fogs, Average Gradients, MTFs and WSs for Screen-Film, Processing Combinations*

Screen	Dev. Temp. [℃]	Proc. Time [sec]	Film CM-H			
			Fog	Ave. Gradient	MTF	WS ($\times 10^{-5}$)
M-100	30	210	0.18	3.00	0.70	2.21
	32	210	0.19	3.02	0.70	2.60
	34	210	0.20	3.12	0.68	2.62
	34	90	0.18	2.64	0.72	1.81
M-200	34	90	0.18	2.60	0.63	1.47

*The x-ray exposures were made at 28 kV (HVL : 0.31 mmAl). MTFs and WSs show values at 2.5 and 1.0 cycles/mm, respectively.

4. Visibility

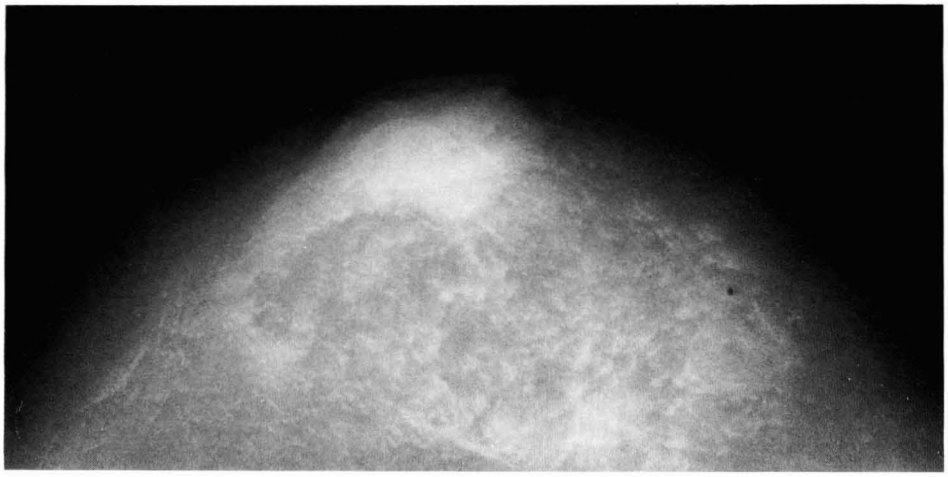
Fig. 5 shows the images in M-200/CM-H, 34℃−90 seconds and M-100/CM-H, 34℃−210 seconds combinations. Fig. 6 shows the results of the method of paired comparison and the scales indicate subjective evaluation. The scale value in M-100/CM-H, 32℃−210 seconds combination was highest in evaluating masses and fibers. In detecting specks, M-100/CM-H, 34℃−210 seconds combination was best.

Table 2 shows the entrance skin exposures

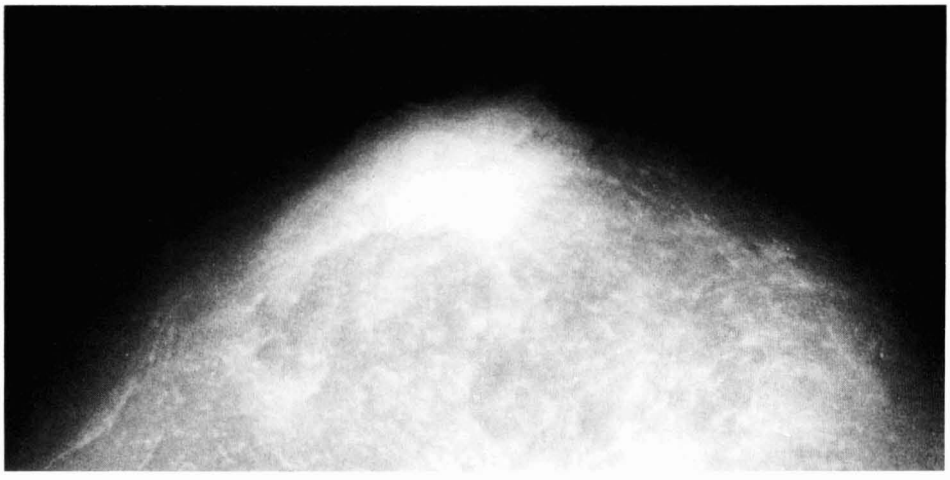
Table 2 RMI 165 Phantoms Entrance Skin Exposures*

Screen	Dev. Temp. [℃]	Proc. Time [seconds]	Film CM-H	
			mAs	Dose [mR]
M-100	30	210	40	407.3
	32	210	25	256.5
	34	210	20	199.8
	34	90	40	407.3
M-200	34	90	25	256.5

*Entrance skin exposures in mR needed to achieve 1.5 average optical density for the RMI 165 phantom when exposed to 28kV without grid in standard- and extended- cycle process for selected screen-film combinations.



(a) M-200/CM-H
34℃, 90 seconds
28 kV, 25 mAs



(b) M-100/CM-H
34℃, 210 seconds
28 kV, 20 mAs

Fig. 5 Test object images of RMI 165 phantom
The masses were made by using thin vinyl chloride sheets and specks were glass beads with the diameter of 100-150 μm. The sheets and glass beads as focuses were inserted into the phantom.

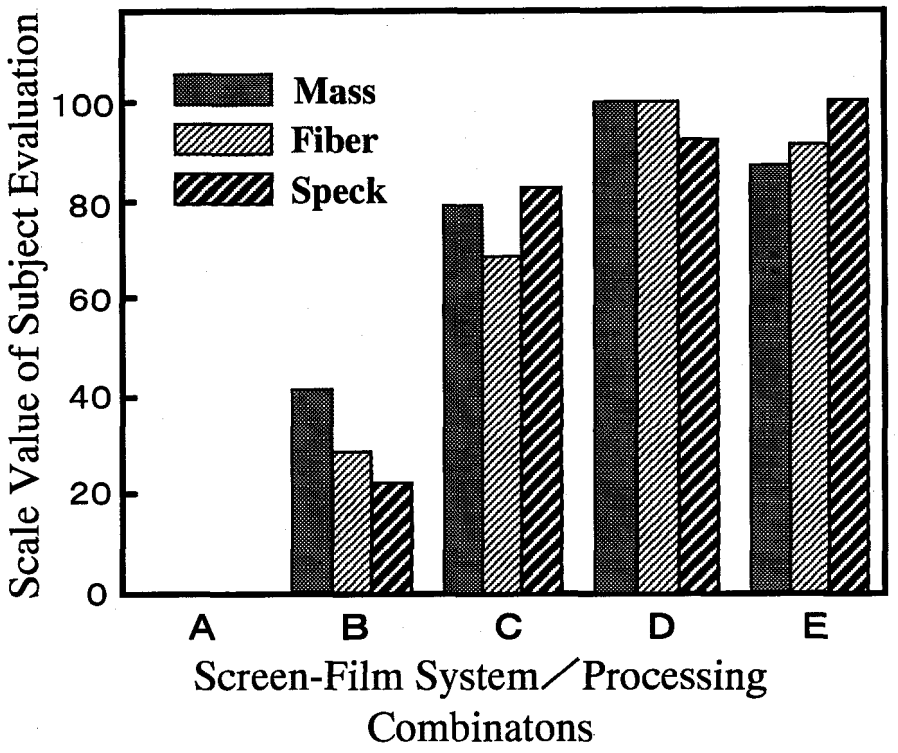


Fig. 6 Scale value of subjective evaluation of five screen-film system/processing combinatons as the followings.
A: M200/CM-H, 34℃, 90 seconds, **B**: M100/CM-H, 34℃, 90 seconds,
C: M100/CM-H, 30℃, 210 seconds, **D**: M100/CM-H, 32℃, 210 seconds,
E: M100/CM-H, 34℃, 210 seconds

for producing the test object image. It was possible to reduce dose in M-100/CM-H, 34℃－210 seconds combination with improving visibility. In M-100/CM-H, 32℃－210 seconds combination, it was possible to improve visibility with the dose equal to M-200/CM-H, 34℃－90 seconds combination.

Discussion

The speed of M-100/CM-H can be increased by the extended-cycle process. This may permit to use the system at the radiation dose almost equal to M-200/CM-H, and the film contrast also may be increased. In the extended-cycle process the MTF value of M-100/CM-H in the standard-cycle process couldn't be kept. The reason was considered as the following. Almost all of density was produced by the fluorescence from screen, and some of density was produced by only direct x-ray exposure. The direct x-ray exposure may produce mammogram with less image blur than the exposure by the fluorescence from screen, because the light (the fluorescence) diffusion causes blurring. That is, the direct x-ray exposure dose in M-100/CM-H, 34℃－210 seconds combination is less than it in M-100/CM-H, 34℃－90 seconds combination due to the increase of film speed by extended-cycle process. However the MTF value of M-100/CM-H in the extended-cycle process was higher than it of M-200/CM-H in standard-cycle process.

In extended-cycle process the visibility of M-100/CM-H was improved thougt the MTF

value was decreased. It can be considered that the result was mainly caused by the increase of film contrast.

On the other hand, the extended-cycle process caused fog density, quantum mottle and radiographic noise to increase. In addition, when film contrast was increased too much, visibility may fall off, that is, extended-cycle process does not always result in improving image quality. In the case of M-100/CM-H, 34℃−210 seconds combination, the film contrast was slightly higher, and the visibility was less than it in M-100/CM-H, 32℃−210 seconds combination at mass and fiber. WSs of M-100/CM-H with the extended-cycle process were worse as compared to it in M-200/CM-H, 34℃−90 seconds combination, and the fog densities slightly increased also. However the changes for the worse seem not to be significant problem from the results of visibility.

Conclusion

Using the extended-cycle process (32 or 34℃−210 seconds) for the lower speed, high-resolution system, M-100/CM-H, it was possible to increase the speed as much as the higher speed system, M-200/CM-H. The contrast, the MTF and the visibility were also improved. The extended-cycle process is useful for M-100/CM-H, and it was suggested that changes for the worse in noise property and fog density were not significant problems in our extended-cycle process condition.

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(原　著)

Extended-cycle processによる乳房撮影用増感紙／フィルムシステムの画質改善

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抄　　録

通常，extended-cycle processは処理時間が約210秒に延ばされた現像機のために使われる用語である。乳房撮影に使われるような片面乳剤フィルムにおけるextended-cycle processは，フィルムコントラストを増し，感度をあげることが良く知られている。そこで，本論文ではextended-cycle processにより低感度，高解像度システムの感度を上げ，どの程度解像度が維持されるかを調べた。片面増感紙／片面フィルムの組合わせであるKonica M-100/CM-Hを低感度，高解像度システムとして用いた。露光後のフィルムは現像温度30，32，34度，処理時間210秒の異なる組合わせで現像処理した。一方，高感度システムとしてKonica M-200/CM-Hを用い，このフィルムは標準現像(34℃，90秒)された。感度，増感紙／フィルムのぼけ，雑音に関して，特性曲線，MTF(modulation transfer function)，WS(wiener spectrum)によってこれらのシステムを比較した。さらにこれらのシステムにおける乳房写真の細部視覚評価のためにRM165ファントムを使用した。

その結果，M-100/CM-Hに対するextended-cycle process現像温度32，34℃，処理時間210秒のextended-cycle processにおいて，高感度システムM-200/CM-Hと同等の感度を上げることが可能であった。そのとき，コントラスト，MTF，視覚的検出能も高感度システムより向上した。さらに，現像温度34℃，処理時間210秒では，被曝線量の低減が可能であった。

キーワード：image quality, mammography, single screen-single emulsion film system, high-resolution screen, extended-cycle process

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