

NOLTR 68-39

AD 668697

A METHOD FOR CLASSIFYING X-RAY FILM

12 MARCH 1968

NOL

UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND

NOLTR 68-39

This document has been approved for public release and sale, its distribution is unlimited.

DDC  
RECEIVED  
MAY 9 1968  
C

Reproduced by the  
CLEARINGHOUSE  
for Federal Scientific & Technical  
Information Springfield Va 22151

38

UNCLASSIFIED  
NOLTR 68-39

A METHOD FOR CLASSIFYING X-RAY FILM

Prepared by:

D. Polansky and E. L. Criscuolo

ABSTRACT: A study has been conducted to evaluate the parameters that could be used to characterize X-ray film. Factors such as speed, graininess, resolution, contrast and uniformity of emulsion are discussed. Recently developed methods of measuring resolution such as the modulation transfer function will be reviewed. At the present time it is felt that the characteristics of speed and average gradient should form the basis of a film classification system. It is proposed that a contrast-speed index  $\eta = \bar{G} \sqrt{r}$  be used to characterize X-ray film.  $\bar{G}$  is defined as the average gradient between two arbitrary densities  $d_1$  and  $d_2$ , and  $r$  is the number of roentgens necessary to produce the density midway between  $d_1$  and  $d_2$ .

U. S. NAVAL ORDNANCE LABORATORY  
WHITE OAK, MARYLAND

i  
UNCLASSIFIED

UNCLASSIFIED

12 March 1968

NOLTR 68-39

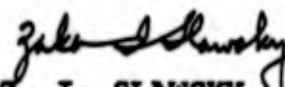
A METHOD FOR CLASSIFYING X-RAY FILM

This report contains information on a proposed method for classifying industrial X-ray film. The objective of this study was to develop a test method and not to evaluate the films produced by various manufacturers. The test method has not been adopted by the Navy Department.

This study was supported by Task ORD-033-211 F008 08 11 Pr 006, sponsored by the Naval Ordnance Systems Command.

Mr. Donald P. Case of the X-ray Laboratory Staff assisted in this work by gathering the film data. His contribution is hereby acknowledged.

E. F. SCHREITER  
Captain, USN  
Commander

  
Z. I. SLAWSKY  
By direction

CONTENTS

	Page
INTRODUCTION . . . . .	1
REQUIREMENTS OF AN X-RAY FILM CLASSIFICATION SYSTEM	2
FILM PARAMETERS . . . . .	2
FILM RESOLUTION . . . . .	3
FILM CONTRAST-SPEED . . . . .	4
MEASUREMENT OF SPEED AND AVERAGE GRADIENT . . . . .	5
SUMMARY . . . . .	10
REFERENCES . . . . .	12

ILLUSTRATIONS

Figure 1 Contrast versus Minimum Hole Size

TABLES

Table	Title	Page
1	Film Speed and Contrast Range . . . . .	1
2	Speed and Gradient of Films with 10 Mev	7
3	Contrast-Speed Index . . . . .	8
4	Contrast-Speed Index . . . . .	9

**BLANK PAGE**

INTRODUCTION

1. Existing methods of classifying X-ray films are proving inadequate in differentiating between industrial X-ray film types. There are several reasons for this situation. Automatic processors with their relatively short cycle from exposed film to dry radiograph have modified the characteristics of film. The processing cycle with its higher temperatures required changes in the developing solution; this affected the granular appearance of some films. In addition, the continuing demand for increased resolution and finer grained film resulted in the introduction of several new X-ray films. The result has been that there is no method to classify the newly developed film. One can purchase as many as a half-dozen different films that are characterized as having high contrast and fine grain.

2. One of the early systems for rating industrial film was given in a paper by Kahn, Imbembo and Bland, presented to the Annual Meeting of the American Society for Testing and Materials in 1949.<sup>1/</sup> They rated film as to Type I or Type II with Type II being the film used with fluorescent screens. Within Type I they differentiated between films by the speed rating for a net density of 1.0 and 1.25. The slowest film was designated as having very fine grain and high contrast while the fastest film (about 15 times faster) was described as extremely fast, moderately high contrast.

3. In 1957, the Navy published an interim Federal Specification for Film, Radiographic, Industrial and Medical.<sup>2/</sup> This specification followed the ASTM published system as to class and type of film. In addition it had a table which listed the speed at several energies.

Table 1 <sup>2/</sup>

Film Speed and Contrast Range					
Type	Class	100 kv range*	200 kv range*	Gamma Ray*	Average Gradient
I	1	2.0-3.8	2.1-2.2	0.1-0.4	3.0-3.5
	2	5.2-9.5	2.5-5.2	0.5-1.0	2.5-3.0
	4	17.0-29.4	6.5-12.0	1.0-2.1	2.2-2.8
II	1	6.0-11.5	3.0-6.5	0.5-1.5	1.7-2.2

\*Film speed as given is proportional to the numerical rating - the larger number indicates less roentgens are required to achieve a given film density.

UNCLASSIFIED  
NOLTR 68-39

Here the energy dependence of a film can be noted and at a given energy the finer grain film has the slowest speed. The final table in that specification lists the classes and identifies several films in each class. Unfortunately the wide latitude of speed within a given class gave rise to the question of differentiating between the films in a given class. The inability of this system to classify newly developed films and its large speed variation at a given energy indicated an improved classification system should be developed.

REQUIREMENTS OF AN X-RAY FILM CLASSIFICATION SYSTEM

4. If we are to update the present system of film classification we should meet some rather broad requirements. The system should characterize film response at different X-ray energies including the effect of processing which may be manual or automatic using different chemical systems. The classification system should be flexible enough to include future film changes and developments. If possible it should also be definitive so that differences in the response of a particular film in a complete exposure-development cycle can be noted.

FILM PARAMETERS

5. Speed is defined as the reciprocal of the exposure, measured in roentgens, required to achieve a given density above the base and fog densities. It is generally agreed that speed can be measured to an accuracy of  $\pm 20$  percent. The generality, the faster the film the grainier the film and its converse introduces the parameter of graininess. This parameter is so closely related to speed that we will assume that a system that will differentiate between the speeds of a film will of necessity indicate differences in graininess.

6. The aging property of film is specified by the manufacturer when he puts an expiration date on his box of film. What is implied by this date is that the speed and average gradient of the film are within the tolerance of a specification.

7. The uniformity of the emulsion on a given sheet is probably best indicated by a comparison to a visual reference standard. This is a quality control task of the manufacturer. The user can judge this parameter by the system response of the film in his own particular set of circumstances.

8. The average gradient is defined as the slope of the straight line drawn on the density-log exposure curve between two arbitrary chosen densities above the base and fog density.

In discussions with several film manufacturers it was generally agreed that this parameter could be measured to  $\pm 10\%$ . For a given change in material thickness, the higher the film contrast the easier it is to see the density difference. Industrial X-ray film therefore has been developed with increasingly higher gradients in order to increase the reliability of film interpretation.

9. One of the more informative features of film, its resolution, is one of the most difficult to measure in radiography. At the present time there is no agreement on a means of measuring resolution but we feel a discussion of recent experimental work is worthwhile.

#### FILM RESOLUTION

10. The resolving power of a film is described as the ability of photographic emulsions to record fine detail. While this definition is quite general, it is important to bear it in mind while discussing various methods of measurement in order to see that the method fills this requirement. Graininess is an indication of resolution but it is difficult to measure. It also does not take into account the effect of screens on image resolution. Because of these difficulties no attempt has been made to evaluate the film by this parameter at the present time. Other methods of resolution measurement are visibility of holes, unsharpness and spatial frequency.

11. The threshold visibility of holes in a test object has been used to indicate film resolution. An absorber with several shims of different thickness each containing a series of holes with decreasing diameter is radiographed. Then the relative contrast  $\frac{\Delta X}{X}$  is plotted on log-log paper against the smallest hole diameter perceptible. The plot is a family of parallel straight lines, the position of the lines being an indication of film resolution. An example of a curve is shown in Fig. 1. The position of the lines is related to the signal to noise ratio and at the center of the curve follows the relationship 3/

$$C = \frac{k}{d}$$

C = contrast

d = hole diameter

k = constant related to the  
threshold signal to noise  
ratio

UNCLASSIFIED  
NOLTR 68-39

It should be noted that as the hole diameter is increased the contrast level reaches a lower threshold. This threshold contrast is the limit for the detection of large areas. As the contrast is increased the smallest hole size detectable reaches a minimum. These limits are shown by the dotted lines. The method of measurement is of small value in evaluating film resolution since the limits of detection appear to vary considerably among several readers.

12. Film unsharpness is also used to evaluate resolution. In the measurement of unsharpness, a radiograph of a step edge is made. By means of a scanning microdensitometer a density profile is measured and a numerical value of unsharpness is obtained by Klassens method.<sup>4/</sup> This method does not take into account the shape of the curve. It attempts to fit a straight line for the "S" shaped unsharpness curve. Obtaining and measuring the unsharpness curve is difficult because the object edge must be carefully aligned with the X-ray beam.

13. In addition, all other unsharpnesses in the system must be reduced so that they are negligible. While this method is valuable it does not give a number that indicates an absolute value of resolution.

14. More recently, the line spread function and modulation transfer function have been used to evaluate films. The line spread function can be described as the resulting intensity distribution on a film due to a line of radiation of microscopic width. This intensity distribution produces on the film a density variation that has a bell shape. By convoluting this function with a sine function the spatial frequency concept can be introduced. This convolution is called the modulation transfer function. The results obtained give information similar to the line test chart used in specifying TV resolution.

15. Recent experiments<sup>5/</sup> have enabled direct measurement of the spatial frequency of films at 10 Mev. This work is still in progress and does offer a possible method for the measurement of radiographic resolution of film. In this film classification work no attempt has been made to include this parameter.

FILM CONTRAST-SPEED

16. Of the parameters discussed it appears that the measurement of speed and average gradient gives reproducible numbers. The question one asks is, "Can these numbers be combined to produce an index that differentiates between film?"

17. Film speed is inversely associated with resolution; in general, the faster the film the poorer the resolution. Film speed is also an inverse measure of the number of photons and photoelectrons that interact with the film. With these interactions there is associated the statistical deviation of a random process that is proportional to the square root of the number of events. One can assume that the recording ability of the film is proportional to  $\sqrt{r}$  where  $r$  = roentgens incident on the film. Thus  $\sqrt{r}$  is one parameter used in the establishment of a film index.

18. Film gradient, the other parameter, is the slope of the density-log exposure curve at a given point. The average film gradient is the slope between two arbitrary density points. Increased film resolution is reported to be a direct result of higher film gradients. One can assume therefore that the film contrast index is proportional to the average gradient. Combining the two parameters into a single film contrast-speed index  $\eta$ , where  $\eta = \bar{G} \sqrt{r}$  should give us a number characteristic of a given film type.

#### MEASUREMENT OF SPEED AND AVERAGE GRADIENT

19. We have had considerable interest in the past few years in the use of betatron radiation for the inspection of propellant. The use of this energy range for film classification meets our immediate needs. The experimental technique used to gather the film classification data was as follows:

Energy	-	10 Mev
Absorber	-	3 HVL of propellant placed adjacent to the film
Intensifying Screens	-	.060" lead front .010" lead back
Processing Equipment	-	Kodak Model B Processor with liquid chemicals

The radiation field was such that density variation across the film was no greater than 0.04. Strips of film one inch wide by three inches long were placed in a 14"x17" cassette. Films of the three major U. S. manufacturers were used. A series of exposures were made, the entire series of film developed and the densities read on a Macbeth Ansco Densitometer. The data were plotted on semi logarithmic paper (density - log exposure) and from these plots the values

UNCLASSIFIED  
NOLTR 68-39

of average gradient and relative speed were obtained, as shown in Table 2.

20. In this data it is noted that the average gradient between densities of 2.0 and 4.0 gives values that distinguish between films in a given class. The gradients at the lower density range are equivalent for at least six films. It appears that this measurement can be of value in a classification system. Since the measurements at 10 Mev gave encouraging results it was decided to make additional measurements at 200 kvp. The 200 kvp data were taken in a manner similar to the method used at 10 Mev. The energy of 200 kvp was achieved as specified in ASA PH 2.8, Sensitometry of Industrial X-ray Film.<sup>6/</sup>

21. Table 3 shows the contrast-speed index at two different energies and with two values of  $\eta$ .  $\eta_1$  is calculated with the average gradient between densities of 0.5 and 2.5 and  $\sqrt{r}$  is measured at a density of 1.5.  $\eta_2$  is calculated with the average gradient between densities of 2.0 and 4.0 and the  $\sqrt{r}$  is at a density of 3.0. The film strips in this comparison were developed by hand at 68°F in Kodak chemicals designated as MX542.

22. Let us look at the contrast-speed values in relation to our objective. A differentiation is maintained between the classes. Within a given class there is a significant difference between several films. The system does not become obsolescent with the introduction of finer grained film (slower speed) or film with increased gradients.

23. Let us refer to the table again and briefly consider the effect of X-ray energy. At these two energies the values are generally consistent with each other with the exception of the new films recently introduced. If this difference is consistent when checked again it may be necessary to have tables of  $\eta$  versus selected X-ray energies.

24. As previously stated we had an immediate interest in the response of films used in the X-ray range of 1-25 Mev. The two sets of films that were exposed simultaneously at 10 Mev with those listed in Table 3 were developed in different developer systems. The second set was developed in a Model B X-OMAT with Hunt liquid chemicals and the third set was hand developed in Kodak chemicals, MX542. Following the established procedure of plotting the characteristic curves, measuring the average gradients at the selected points and determining the exposure to give the required densities, we calculated the contrast-speed index,  $\eta$ . Table 4 lists the results obtained.

TABLE 2  
 Speed and Gradient of Films with 10 Mev

Film no.*	ASTM Class	Relative Speed		Average Gradient	
		at D=1.5	at D=3.0	.5-2.5	2.0-4.0
1		1.5	.7	3.0	4.7
2		1.7	.8	2.9	5.3
3	1	2.7	.9	2.2	4.2
4	1	2.7	.9	2.7	4.1
5	1	3.2	1.5	2.9	6.1
6	2	19.6	9.0	2.7	5.5
7	2	11.9	3.3	2.5	3.3
8	2	13.9	6.4	3.1	4.9
9**		1.0	.4		

- \* X-ray films are from Ansco, Dupont and Kodak. Films are numbered from one through nine  
 \*\* Film number 9 was arbitrarily selected as having unit speed to reach a density of 1.5

UNCLASSIFIED  
NOLTR 68-39

TABLE 3  
Contrast-Speed Index

Film No.	ASTM Class	$\eta_1$		$\eta_2$	
		10 Mev	200 kvp	10 Mev	200 kvp
1		5.6	5.1	19.2	14.3
2		7.5	5.4	32.6	15.6
3	1	2.6	2.0	7.9	7.3
4	1	2.4	2.9	13.3	11.1
5	1	3.8	3.2	13.8	11.7
6	2	1.1	1.1	3.1	3.4
7	2	1.4	1.4	4.9	4.2
8	2	1.6	1.4	5.3	4.2

TABLE 4  
 Contrast-Speed Index

Film No.	Class	$\eta_1 = G_1 \sqrt{I_{1.5}}$				$\eta_2 = G_2 \sqrt{I_{3.0}}$			
		X-OMAT		Hand Dev.		X-OMAT		Hand Dev.	
		MX589 Chemical	Hunt Chemical	Rapid X-ray Chemical	Hand Dev.	MX589 Chemical	Hunt Chemical	Rapid X-ray Chemical	Hand Dev.
1		4.7	3.8	5.6	13.2	11.0	19.2		
2		3.9	5.8	7.5	13.9	20.0	32.6		
3	1	2.0	1.6	2.6	6.4	5.0	7.9		
4	1	2.4	1.9	2.4	7.0	6.8	13.3		
5	1	3.1	3.8	3.8	10.5	8.8	13.8		
6	2	1.1	1.0	1.1	2.6	3.0	3.1		
7	2	1.1	1.8	1.4	3.7	3.0	4.9		
8	2	1.2	.9	1.6	3.6	3.5	5.3		
9		2.2	2.0	2.2	6.4	6.0	9.2		

UNCLASSIFIED  
NOLTR 68-39

25. In this table it is noted that the two liquid developers in general give similar results; that is, the previously designated classes of film give separated values of  $\eta$ . Within a given class it is noted that one developer gives superior results, that is, film number 7 if used at  $\eta_1$  level appears better suited to the Hunt chemistry. At the  $\eta_2$  level an advantage in chemistry is not evident for this film. At the  $\eta_1$  level all three chemistries give compatible results with a slight difference in films 1 and 2.

26. At the higher density level, the development of film by hand at 68°F gave consistently higher index values. This is in agreement with the observed fact, that developing film at increased temperatures (both X-OMATS operated at 81°F) increases the apparent graininess of a film. Since increased graininess degrades resolution at the minimum observable threshold limits, the decreasing values of  $\eta$  for automatic processors is in the right direction.

27. For the facilities that use megavolt radiation and automatic processors it is concluded that the calculation and tabulation of  $\eta_1$  and  $\eta_2$  values will be of value in determining film response in the complete radiographic system.

SUMMARY

28. Many of the parameters that can be used to classify film are very difficult to measure. As a result of this study it was found that the film speed and average gradient can be used for this purpose. While resolution is an important consideration, it is not advisable at this time to use it to rate film.

29. A simple method of combining film gradient and speed is to take the product of the average gradient and the square root of exposure ( $\bar{G} \sqrt{r}$ , where exposure is defined as the roentgens incident on a film to achieve a given film density). This product is defined as the film contrast-speed index  $\eta$ . Experimental results at 200 kvp and 10 Mev indicate that the index can distinguish between film types. The development of three sets of film in three different chemistries also showed that this method of classifying film gives consistent and distinctly different values of  $\eta$  for the different classes of film.

30. In conclusion, this method of classifying film has the following advantages:

**UNCLASSIFIED**  
**NOLTR 68-39**

1. It gives a separate number for each film type and does show differences between different films.
2. It is simple to use and to calculate.
3. It provides for the future introduction of new films.

It is proposed that the contrast-speed index be used as the means of classifying film.

UNCLASSIFIED  
NOLTR 68-39

REFERENCES

- 1/ N. A. Kahn, E. A. Imbembo and J. Bland - "Film Rating Factors for Industrial Radiographic Film for Use with Universal Exposure Calculator," presented to 1949 Annual Meeting of the American Society for Testing and Materials.
- 2/ Specification for Film, Radiographic, Industrial and Medical - W.F-00350 Navy-Ships, 28 August 1957.
- 3/ D. T. O'Connor and E. L. Criscuolo - "The Quality of Radiographic Inspection," ASTM Bulletin #213, April 1963.
- 4/ H. A. Klassens - "Measurement and Calculation of Unsharpness Combinations in X-ray Photography," Philips Research Reports, Vol. I, No. 4, pp 241-249, Aug 1946.
- 5/ E. L. Criscuolo and C. H. Dyer - "Measurement of Spatial Frequency Response of Radiographs," presented to the Society for Nondestructive Testing, Fall, 1965.
- 6/ American Standard Method for the Sensitometry of Industrial X-ray Films for Energies up to 3 Million Electron Volts - American Standards Association, PH 2.8, 1964.

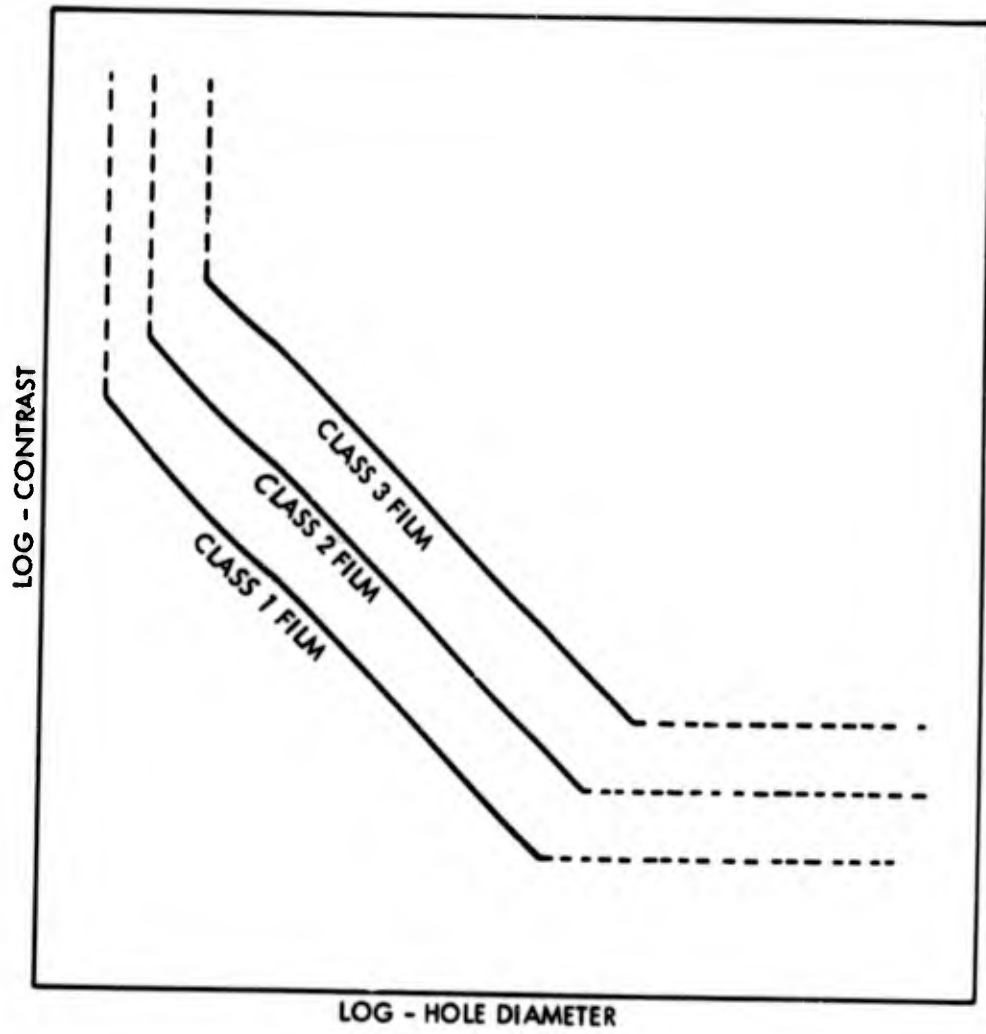


FIG. 1 MINIMUM HOLE SIZE VS CONTRAST

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) U. S. Naval Ordnance Laboratory White Oak, Silver Spring, Maryland 20910		2a. REPORT SECURITY CLASSIFICATION <b>UNCLASSIFIED</b>	
		2b. GROUP ---	
3. REPORT TITLE  A METHOD FOR CLASSIFYING X-RAY FILM			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates)			
5. AUTHOR(S) (First name, middle initial, last name)  Daniel Polansky and Edward L. Criscuolo			
6. REPORT DATE 12 March 1968		7a. TOTAL NO. OF PAGES 12	7b. NO. OF REFS 6
8a. CONTRACT OR GRANT NO.		9a. ORIGINATOR'S REPORT NUMBER(S)  NOLTR 68-39	
b. PROJECT NO. ORD 033-211 F008 08 11 Pr 006		9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
c.			
d.			
10. DISTRIBUTION STATEMENT  Distribution of this report is unlimited.			
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY	
13. ABSTRACT  A study has been conducted to evaluate the parameters that could be used to characterize X-ray film. Factors such as speed, graininess, resolution, contrast and uniformity of emulsion are discussed. Recently developed methods of measuring resolution such as the modulation transfer function will be reviewed. At the present time it is felt that the characteristics of speed and average gradient should form the basis of a film classification system. It is proposed that a contrast-speed index $\eta = \bar{G} \sqrt{r}$ be used to characterize X-ray film. $\bar{G}$ is defined as the average gradient between two arbitrary densities $d_1$ and $d_2$ , and $r$ is the number of roentgens necessary to produce the density midway between $d_1$ and $d_2$ .			

UNCLASSIFIED

Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
X-ray Film Response X-ray Film Characteristics Film System Response						