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COMPARISON OF IMAGE QUALITY OF NUCLEAR FUEL NEUTRON RADIOGRAPHS TAKEN ON SILVER HALIDE AND NITROCELLULOSE FILM

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Abstract. Paper accepted for presentation on 19.11.1979 to the Ninth World Conference on Non-Destructive Testing in Melbcurne, Australia.

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COMPARISON OF IMAGE QUALITY OF NUCLEAR FUEL NEUTRON RADIOGRAPHS TAKEN ON SILVER HALIDE AND NITROCELLULOSE FILM

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SUMMARY: For the assessment of image quality of nuclear fuel by neutron radiographs the ASTM methods seems inadequate; therefore another method was tested, used previously for the assessment of the accuracy of dimension measurements. Silver halide and nitrocellulose films were used in the comparison.

I. INTRODUCTION

The ASTM E 545-75 Standard Method for Determining Image Quality in Thermal Neutron Radiographic Testing (1) has been developed as a universal method for neutron radiography. It recognizes that the only truly valid sensitivity indicator is a reference standard comparison part. Such a reference part, in the form of a calibration fuel pin (CFP) has been designed and produced at Risø for the assessment of the accuracy of pellet diameter and pellet-to-clad gap measurements of nuclear fuel pins. This method is described in (2).

The calibration fuel pin, together with the ASTM indicators, was neutron radiographed on silver halide (X-ray) film using the direct and the transfer method as well as on nitrocellulose film. The quality levels were thereafter determined and the overall quality of the CFP radiographs judged. A comparison was made of the image quality of radiographs on X-ray and nitrocellulose films and it was attempted to find a correlation between ASTM and CFP findings.

II. NITROCELLULOSE FILMS FOR NEUTRON RADIOGRAPHY

The relative merits of nitrocellulose vs silver halide films for neutron radiography are known and cited by several authors, e.g. (3), but the quality of their image was not systematically investigated. It depends on many parameters such as etching temperature and time. The assessment of neutron radiographs on nitrocellulose films can give better results if the radiographs are further copied on high contrast graphic films or paper with a photographic enlarger.

To obtain radiographs of maximum quality some of the abovementioned parameters were tested.

x) Work performed under contract with Risø National Laboratory

Today there is practically only one supplier of nitrocellulose films for neutron radiography: Kodak Pathé. It has put on the market the CA 80-15 Type B film (red tinted), for which either a 60°C and 10 - 30 min etching in a 10% solution of NaOH (2.5M) or 25°C and 2 - 8 h etching is recommended.

An investigation performed at Risø with the CFP has shown, however, that best results are obtained at 20°C and 21 h etching.

Recently a new nitrocellulose film has been developed by Kodak-Pathé for neutron radiography. It is the CN 85-B, which is a transparent nitrocellulose film. This film was used in the present investigation. It was etched in a 10% solution of NaOH at 20°C for 21 h.

III. EXPOSURE TECHNIQUE

The ASTM BPI and SI with the CFP were exposed to neutrons at the DR1 Risø neutron radiography facility, described in (4). The L/d ratio in the vertical direction (in which the CFP was located) of the neutron beam was 110 and in the horizontal direction 27.5. Some exposures were also made at larger L/d ratios: 160 and 40 respectively. The neutron flux at the object to be radiographed was 1.6×10^6 n/cm^2s.

Both X-ray (single and double-coated) films as well as nitrocellulose films were used. The X-ray films were exposed either by the direct method, using a 50μm Gd imaging foil or by the transfer method, using a 100μm Dy foil. The X-ray films were the double-coated Agfa Structurix D4 and Kodak Industrex M and the single-coated Kodak SR. Kodak-Pathé nitrocellulose films CA 80-15 Type B (red tinted , 100μm thick) and CN 85-B (colourless) were used. They were coated from both sides with lithium borate converter screens.

Exposure times were 8 and 24 min for the Gd direct method and the SR film (L/d = 110 and 160) and 15 and 45 min for the Dy transfer method and the D4 film. The nitrocellulose films were exposed from 15 min to 2 h. They were etched for 21 h at 20°C.

IV. OVERALL QUALITY OF CFP NEUTRON RADIOGRAPHS

As mentioned before, the calibration fuel pin (CFP) seemed more suited to the quality assessment of nuclear fuel neutron radiographs than the ASTM sensitivity indicators (1). Therefore neutron radiographs of the CFP were assessed by three observers for radiographic image quality. An arbitrary five grade scale (5-very good, 1-very bad) was used in the assessment. As reference, X-ray radiographs of the CFP (taken at 140 kV) were used (they give the sharpest image of the fuel-to-clad gap). Their quality was judged "5".

Fig. 1 shows the results of this assessment. It includes X-ray films exposed to 140 kV X-rays, to neutrons by direct (Gd) and transfer (Dy) methods as well as the

CA 80-15 Type B and CN 85-B nitrocellulose films. The X-ray exposures were made at 60 mm FFD with a 3 mm focus tube.

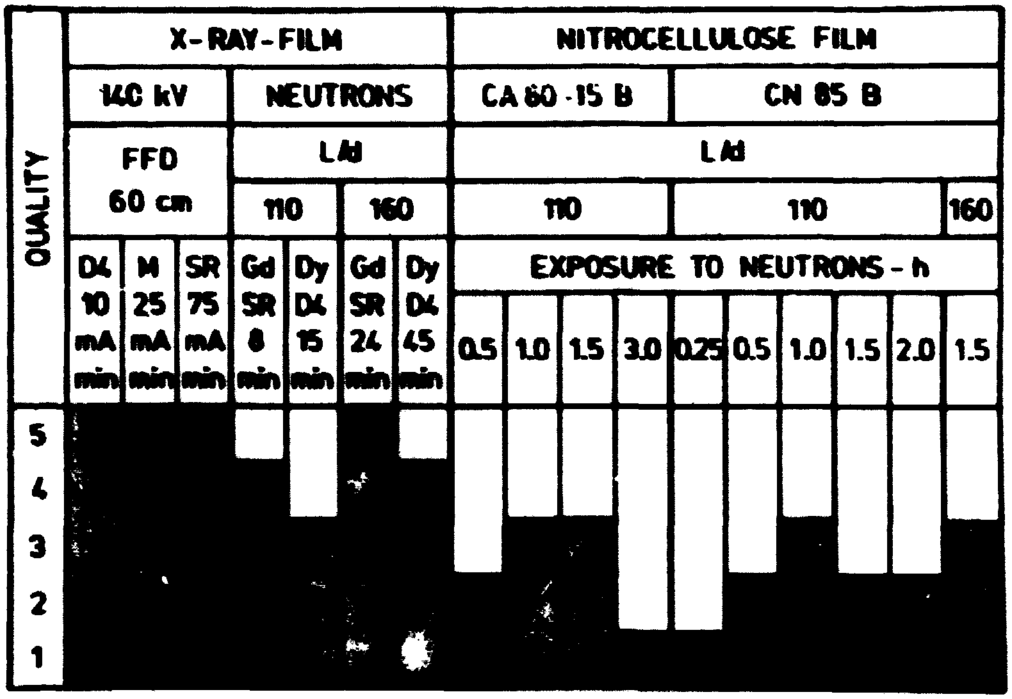

Fig. 1. Overall quality of CFP neutron radiographs.

As can be seen, an overall highest quality "5" equal to that obtained with X-rays could be reached only for the direct exposure method to neutrons (with Gd) with the single-coated SR film and L/d = 160. For both nitrocellulose films a quality "3" was obtained for exposures to neutrons 1 - 1.5 h.

V. MICROSCOPIC AND DENSITOMETRIC EXAMINATION OF NITROCELLULOSE FILMS

To be able to look more closely at the process of track production in the nitrocellulose film used with the track -etch method, microscopic pictures of neutron radiographs were produced. They were taken on Agfapan 100 film with a 630 magnification and were finally enlarged to 2000 times. Microscopic pictures were taken in two regions of the neutron radiographs: under the UO_2 pellet (on the axis of CFP) and at the background. By using a magnifying glass (magnification of 10) diameters of the holes produced in the nitrocellulose film by etching were measured. In all instances mean diameters of the holes in the CA 80-15B film were larger than those of CN 85-B. They usually decrease with exposure time to neutrons (for the same etching temperature and time). For the CA 80-15B film a diameter of about 2.5µm could be measured, whereas for the CN 85-B the diameter could be less than 2.0µm.

The optimal densities of the nitrocellulose neutron radiographs are extremly low as compared with those on X-ray films. They were higher for the CA 80-15B than for the CN 85-B film as measured with a conventional transmission densitometer. The densities increased with exposure time to neutrons. For the optimum exposure of about 1.5 h they were the following: under the pellet - for CA 80-15B about 0.25 and for CN 85-B about 0.1. For the background respectively 0.3 and 0.15.

VI. RADIOGRAPHIC SENSITIVITY BY THE ASTM METHOD

For the determination of the sensitivity levels according to ASTM (1), type A, B, C and D sensitivity indicators were usad. As in the assessment of the overall quality of the CFP radiographs three observers were used to read the radiographs. In the evaluation of sensitivity levels the readings obtained with the A, B and C indicators were taken into account. According to ASTM "the sensitivity level reported is the largest consecutive velue of R that is visible in the image of the sensitivity indicator". Using this procedure the following results were reached for the X-ray and nitrocellulose films exposed in the same conditions as shown for Fig. 1.

Table 1. ASTM Sensitivity Levels R

Sensitivity Indicator	X-ray film				Nitrocellulose film					
	L/d				CA 80-15B				CN 85-B	
	110		160		L/d = 110				110	160
	Gd SR	Dy D4	Gd SR	Dy D4	Exposure to neutrons - h					
					0.5	1.0	1.5	3.0	1.5	1.5
A	3	3	7	3	2	3	3	3	3	3
B	15	11	15	11	3	7	10	11	11	11
C	11	7	15	7	-	-	-	-	7	11

As can be seen the assessment of radiographic sensitivity by the use of the ASTM Type A sensitivity indicator can be misleading. For L/d = 110 on all neutron radiographs (except the 0.5 h underexposed nitrocellulose film) equal sensitivity levels were indicated, whereas the assessment shown in Fig. 1 showed big differences in overall qyality of the CFP radiographs. The use of the Type B sensitivity indicator seems more appropriate. It shows the same sensitivity level R = 11 for L/d = 110 for the best nitrocellulose film radiographs as well as the Dy - D4 X-ray film, whereas for the Gd - SR film highest R is obtained. Similar results were also reached for the overall quality of CFP radiographs. Type C sensitivity indicator could be also used for the purpose of assessment of the nuclear fuel radiographic quality.

VII. ASTM IMAGE QUALITY LEVELS

It is not possible to compare directly ASTM Image Quality Levels of neutron radiographs taken on silver halide and nitrocellulose films. As mentioned in §3 of (1): "Metal conversion screens and silver halide films were used in the development and testing of the beam purity indicator. Use of alternative detection systems may produce density readings of the indicator that are not directly comparable to the formulas in section 10". (Calculation of beam constituents).

The ASTM beam Purity Indicator (BPI) was used throughout this investigation together with the SI and CFP. In spite of the above warning about using the calculation of beam constituents from the BPI readings on nitrocellulose film it may be interesting to see what the results of such calculations would be. This is shown below in table 2.

Table 2. ASTM Image Quality Levels for Type B Sensitivity Indicator.

X-ray film				Nitrocellulose film		
L/d				CA80-15B	CN 85-B	
110		160		L/d		
Gd SR	Dy D4	Gd SR	Dy D4	110	110	160
N74-7-15	N68-5-15	N76-0-15	N71-2-11	N38-0-10	N69-15-11	N60-0-11

As can be seen using the ASTM method for the calculation of neutron beam constituents, one obtains much lower values for the thermal neutron content for the CA 80-15B film and comparable values for the CN 85-B film. In all instances the scattered neutron content has fallen when the L/d was increased.

VIII. THE ACCURACY OF DIMENSION MEASUREMENTS

Some measurements of pellet diameter and fuel-to-clad gaps were made on CFP X-ray and neutron radiographs using a projection microscope, as described in (2). They did not show any improvement in measuring accuracy for the nitrocellulose films. It is probably due to the difficulty in measuring dimensions directly from the nitrocellulose films which are of very low optical density. The red tint of the CA 80-15B film makes the measurements even more difficult. It was almost impossible to perform dimension measurements from nitrocellulose films using a scanning microdensitometer. Some of those difficulties probably be overcome by copying the nitrocellulose neutron radiographs on high contrast graphic-arts film or printing paper. The investigation will be continued in that direction.

IX. CONCLUSIONS

1) If the ASTM method is to be used for the assessment of the image quality of nuclear fuel radiographs then the Type B or C Sensitivity Indicators seem to be the most suitable.

2) As a "reference standard comparison part" (as mentioned in ASTM) a calibration fuel pin could be used. The quality of its radiographic image can be assessed both by judging the overall quality of the radiograph (especially the sharpness of the fuel-to-clad gap) and by judging the accuracy of dimension measurements.

3) Nuclear fuel neutron radiograms on nitrocellulose film require special photographic treatment before they can be assessed and their quality determined.

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