AD-A097 936   ARMY MATERIALS AND MECHANICS RESEARCH CENTER WATERTOWN MA   F/G 14/5
COMPOSITE SCREENS USED AS A RADIOGRAPHIC AID.(U)
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SATRAK DerBOGHOSIAN and ALBERT J. COATES
MATERIALS TESTING TECHNOLOGY DIVISION

March 1981

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

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(14)

1. ~~REPORT NUMBER~~
AMMRC-TR-81-11 ✓

2. GOVT ACCESSION NO.
AD-A09779

3. RECIPIENT'S CATALOG NUMBER
36

6

4. TITLE (and Subtitle)
COMPOSITE SCREENS USED AS A RADIOGRAPHIC AID.

5. ~~TYPE OF REPORT & PERIOD~~ COVERED
9
Final Report.

6. PERFORMING ORG. REPORT NUMBER

11

7. AUTHOR(s)
Satrak DerBoghosian ~~and~~ Albert J. Coates

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Army Materials and Mechanics Research Center
Watertown, Massachusetts 02172
DRXMR-M

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
D/A Project: M6350
AMCMS Code: 53970M6350

11. CONTROLLING OFFICE NAME AND ADDRESS
U. S. Army Materiel Development and Readiness Command, Alexandria, Virginia 22333

12. ~~REPORT DATE~~
11
March 1981

13. ~~NUMBER OF PAGES~~
12

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
12 18

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES
This project has been accomplished as part of the U.S. Army Materials Testing Technology Program, which has for its objective the timely establishment of testing techniques, procedures or prototype equipment (in mechanical, chemical, or nondestructive testing) to insure efficient inspection methods for materiel/material procured or maintained by DARCOM.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Nondestructive tests
Composite screens
Radiography

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

(SEE REVERSE SIDE)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

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Block No. 20

ABSTRACT

Tests evaluating fluorometallic or composite X-ray intensifying screens have shown that these screens can be valuable and useful accessories in the field of industrial radiography. In many applications, they can increase inspection efficiency by reducing exposure times and possibly lowering the kilovoltages which are required when using conventional lead screens.

The radiographic tests were performed using steel plates ranging in thickness from 0.250 to 4.0 inches in the 150 kV to 2.5 MeV radiation quality range with ASTM film classes 1 and 2. Image resolution assessment was based upon penetrameter requirements (2-2T) set forth in MIL-STD-453, Inspection, Radiographic. The resultant radiographs using these screens attained at least the 2-2T quality required by most codes. The high speed screen appears to offer more advantages than the high definition screen.

CONTENTS

INTRODUCTION

In the field of industrial radiography, the absorption by the film of the transmitted radiation energy may be less than one percent. Because of this, intensifying screens are used as amplification devices to make more efficient use of the radiation received by the film.

The relatively recent introduction of composite or fluorometallic intensifying screens represents an interesting development which merits further investigation into their effect on radiographic efficiency and economy.

The object of this report is to examine essential aspects of these screens by evaluating their sensitivity and resolving capabilities utilizing various parameters. First, however, it would be helpful to briefly review intensifying screens in general use.

RADIOGRAPHIC INTENSIFYING SCREENS

Radiographic intensifying screens are used to reduce exposure time and to improve the quality of the radiograph. This is done by the intensification action of the screens which more effectively utilizes the radiation absorbed by the film. Any device, therefore, which can enhance or improve the energy-absorbing process by the film contributes to the X-ray examination process.

At the present time, there are three kinds of screens which are generally being used in the field of industrial radiography; namely, lead, fluorescent, and composite.

Lead intensifying screens are used almost exclusively in the industrial radiographic field. Most codes do not allow the use of fluorescent screens or only by special permission if absolutely necessary. This study will attempt to identify some areas of applications where the fluorometallic or composite screen can be utilized to meet or improve radiographic quality requirements.

Lead Screens

Lead is by far the most common screen material utilized and is available for this purpose in the form of foil mounted on thin cardboard or plastic, or as an oxide applied to a thin base in sheet form with film sandwiched between these sheets. This type of film-screen combination is convenient to use in many applications and is commercially available. What makes lead a desirable screen material is its ability to release photoelectrons and scatter radiation when struck by X-rays. These photoelectrons have enough energy to cause photochemical action in the film emulsion which, in turn, produces film blackening or density. The amount of photoelectrons produced by the X-ray beam determines the intensification effect of the screens.

Generally, lead screens are used in most radiography conducted above 125 kV and are used as front and back screens with the film, of course, in between. The effectiveness of the screen on the film density is called the intensification factor (I.F.) and is determined by dividing the exposure used to produce a given radiographic density with no screens by the exposure required to yield the same density with screens. As stated previously, lead screens are used in pairs with the film in intimate contact with both front and back screen surfaces. Front screen thicknesses range from 0.004 to 0.006 inch with back screens in the 0.010- to 0.012-inch range. However, at voltages between 140 to 250 kV, the maximum intensification factor for the front screen occurs at about 0.001-inch lead thickness. Adding much more than a few thousandths of lead thickness only on the front screen reduces the intensification effect because of primary beam and scattered radiation absorption. The back screen is usually thicker in order to absorb backscattered radiation.

Care must be taken to prevent damage, discoloration, scratches, or impurities in the lead screen since these conditions cause artifacts in the finished radiograph.

In summary, lead causes the following effects when in close contact with a photographic emulsion:

1. The photochemical action on the film is increased because of electrons emitted and by the generation of scattered radiation.

2. The lead absorbs the long wavelength scattered radiation more readily than the shorter primary wavelengths.

3. The primary radiation is intensified more than the scattered radiation.

Fluorescent Screens

Fluorescent intensifying screens emit light rays when subjected to X-rays. The light emitted is directly proportional to the radiation intensity. Calcium tungstate and barium lead sulphate are the two most commonly used compounds for fluorescent screen manufacture since they exhibit the above characteristics. The screens are made by coating a cardboard support with either of the above compounds. Like lead screens, the film is sandwiched between a pair of these screens and placed in a suitable film holder or cassette. The exposure or film blackening is caused by a combination of the X-rays and the light emitted by the screens.

Even though fluorescent screens are widely used in medical radiography, they are used sparingly in industrial radiography and then only under special circumstances, such as attempting to avoid unduly long exposure times with limited equipment or excessive thicknesses. The two main reasons for this are the loss of image quality because of a spreading of the light emitted by the screens and, secondly, by screen mottle which appears to be affected by the amount of absorbed X-ray quanta.

Fluorescent screens require more care than lead screens in that they must be periodically examined for film-screen contact and screen surfaces must be protected from soiling, finger contact, dust, etc. Suffice it to say that fluorescent screens are rarely used and then only in very unusual situations.

Composite Screens

The composite or fluorometallic intensifying screen (Figure 1) is a relatively recent introduction which attempts to combine the best qualities of lead and fluorescent screens into a practical accessory for use in the improvement of radiographic efficiency. This is accomplished by utilizing the luminescence of the fluorescent layer (calcium tungstate) and the secondary electrons from the lead layer. These mechanisms make more efficient use of the radiation striking the film and account for most of the resulting film density.

The composite screens require as much care as fluorescent screens and must be free of any surface soil or scratches.

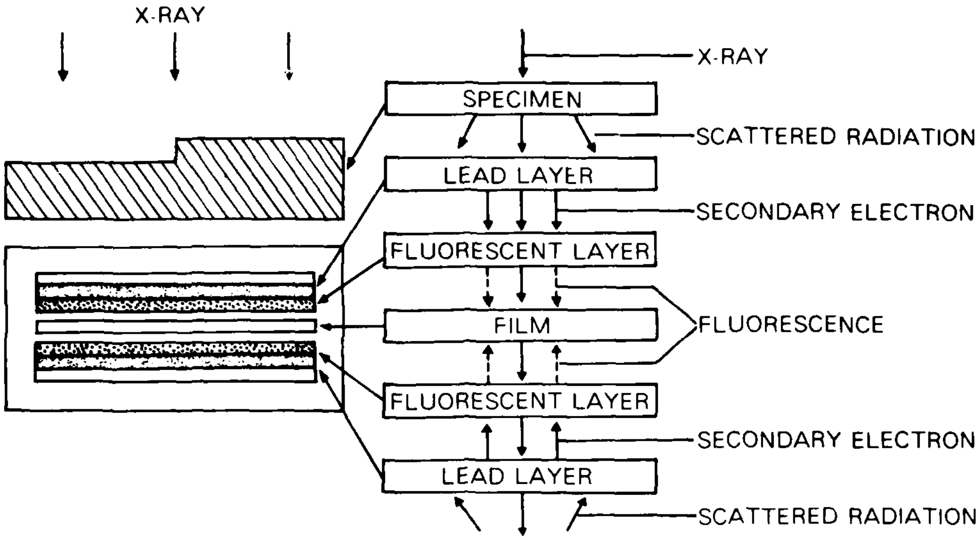

Figure 1. The fluorometallic intensifying screen and composition.

GENERAL DISCUSSION

The composite screens are manufactured in two categories of high speed and high definition which represent the general areas of application. These categories, in turn, are subdivided into three energy levels ranging from 80 kV to 35 MeV. Table 1 shows the various codes selected for each type of screen, the voltages used which are within the range for each type; and the films and their designations utilized for each screen.

Table 1. CODES

a. Screen Designations (X-Ray Source)

Screen	Type	Voltage
18	High Definition	150 kV
38	High Speed	150 kV
13	High Definition	300 kV
33	High Speed	300 kV
11	High Definition	2.5 MeV
31	High Speed	2.5 MeV

b. Film Designations

Film Iden.	ASTM Type E94 Description	Relative Speed
A	1 - Extra-Fine Grain	30
B	2 - Fine Grain	100

TEST PARAMETERS

The composite screens consist of the six types listed in Table 1a, which cover a range of radiation quality from 150 kV to 2.5 MeV even though the screens are manufactured for use in the 80-kV to 30-MeV range. The screens are further divided into two categories of high speed (HS) and high definition (HD), depending upon the application. Two of the most common industrial X-ray films were utilized with the above composite screens and are described in Table 1b. They are the ASTM E94 type 1 and 2 classes which account for the greater majority of industrial radiographic applications. The screens are made to radiograph thin and thick steels using a given radiation quality range.

For purposes of this investigation, the thicknesses for thin steel ranged from 1/4 to 3/4 inch utilizing 150-kV X-rays which fall within the recommended 80- to 200-kV range. Screens HD 18 and HS 38 were used at these thicknesses in 1/4-inch increments. Screens HD 13 and HS 33 were used for intermediate thicknesses, beginning with 1 inch and up to 1-1/2 inches in 1/4-inch increments, utilizing 300-kV X-rays which fall within the recommended 200-kV to 0.66-MeV range. Screens HD 11 and HS 31 were used for thicker steels, beginning with 2 inches and up to 4 inches in 1-inch increments, utilizing 2.5-MeV X-rays which are closer to the recommended lower range of 3 to 35 MeV.

The investigation was conducted by grouping the two screen types of high definition and high speed so that screens of each type were evaluated together. The screens were utilized as recommended by placing film between screens. Even though other approaches in this regard could have been used for evaluation purposes, it was decided to follow manufacturers' procedures. A film density of 2.0 ± 0.20 H&D units was obtained for all exposures with all other conditions held constant for each voltage range.

The effectiveness of the composite screen on film density, which in this case may also be called screen performance, was determined by obtaining the intensification factor. The intensification factor may be calculated by obtaining the ratio of the exposure required to produce a film density of 2.0 H&D units using lead screens to the exposure required to produce the same density with composite screens. This may be written as follows:

$$\text{I.F.} = \frac{\text{Exposure with lead screens}}{\text{Exposure with composite screens.}}$$

The steel specimens radiographed throughout the tests consisted of a series of plates 1/8, 1/4, and 1/2 inch in thickness stacked to make up the required thickness which ranged from 1/4 to 4 inches. In every case, the final 1/8 inch (tube side) consisted of a cracked plate which was used to evaluate the effect of composite screens on image resolution. This was considered important from a fault-sensitivity standpoint. All the above steel plates were a standard 3 × 6 inches, including the top 1/8-inch cracked plate.

For this investigation, radiographic quality levels were determined by using the penetrameter method for lead as well as composite screen radiographs. The penetrameter method is generally utilized in the field of industrial radiography, hence its use here for controlling radiographic quality. The penetrameters utilized are in accordance with the requirements of DoD MIL-STD-453, Inspection, Radiographic, 11 November 1977.

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illus-tables, D/A Project M6350
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Paragraph 1.1.2, radiographic quality levels, states that:

> "Three minimum quality levels listed in Table II may be assigned on the basis of the perceptibility of one, two, or three holes in the penetrameter image on the radiograph. The quality level shall be specified by the procuring activity. Unless otherwise specified, all radiographs of aeronautical components shall show the image of at least two holes (quality level 2-2T) and the outer edge of the penetrameter panel.
>
> "Table II - Radiographic Quality Levels
>
> | Radiographic Quality Level | Minimum Perceptible Penetrameter Hole | Equivalent Sensitivity, % |
> |---|---|---|
> | 1 | 1T | 0.7 |
> | 2 | 2T | 2.0 |
> | 4 | 4T | 2.8." |

Quality level 1 is specified as 1-1T (where T equals material thickness radiographed) and indicates the showing of the 1T hole in a penetrameter whose thickness is one percent of the material thickness. This is a special quality level and will be considered above standard for this report and will be rated as such.

Quality level 2 is specified as 2-2T and indicates the showing of the 2T hole in a penetrameter whose thickness is two percent of the material thickness. This quality level is specified as the standard radiographic quality required by most radiographic specifications and codes including MIL-STD-453. Therefore, radiographs bearing the 2T hole will be given a standard rating.

Quality level 4 is specified as 2-4T and indicates the showing of the 4T hole in a penetrameter whose thickness is two percent of the material thickness. This quality level will be rated as below standard. The image of the cracked plate placed on top of the plates built up for the required thickness will be evaluated based upon a standard radiograph made for that thickness and will be rated as acceptable (A) or not acceptable (NA).

TESTS PERFORMED

The composite screen evaluation tests were conducted with both the high speed and high definition screens at the appropriate kilovoltage beginning with 150 kV, 300 kV, and finally 2.5 MeV. Test results are presented in Table 2.

a. The HD 18 screen was used in radiographing thicknesses from 0.250 to 0.750 inch of steel at 150 kV. Tests at this kilovoltage indicate significant increases in radiographic speed, up to about 4.5 times faster than conventional lead screens. Image quality appears to be somewhat better at greater thicknesses. At 150 kV, the I.F. seems to diminish somewhat with increasing plate thickness. Even though some composite screen mottle has been noted, it does not appear to significantly effect image quality; in fact, penetrameter contrast sensitivity appears to be slightly enhanced. Film types 1 and 2 were used for these tests with the faster film (type 2) showing the greatest gain in I.F.

Table 2. RESULTS FROM SCREEN EVALUATION TESTS

Screen	Radiation	Plate Thickness (in.)	Exposure	Screen Type	ASTM Film Type	Radiographic Quality	Crack Image	I.F.
a. HD 18	150 kV	0.250	1	Pb	1	2T	A	
			2	Pb	2	4T	NA	
			3	18	1	2T	A	4.0
			4	18	2	N/A*	NA	4.0
		0.500	5	Pb	1	1T	A	
			6	Pb	2	4T	NA	
			7	18	1	1T	A	3.5
			8	18	2	2T	A	4.5
		0.750	9	Pb	1	1T	A	
			10	Pb	2	2T	A	
			11	18	1	1T	A	1.83
			12	18	2	2T	A	2.0
b. HD 13	300 kV	1.0	13	Pb	1	1T	A	
			14	Pb	2	2T	A	
			15	13	1	1T	A	2.0
			16	13	2	2T	A	2.43
		1.25	17	Pb	1	1T	A	
			18	Pb	2	1T	A	
			19	13	1	1T	A	1.67
			20	13	2	1T	A	2.33
		1.50	21	Pb	1	1T	A	
			22	Pb	2	1T	A	
			23	13	1	1T	A	1.50
			24	13	2	1T	A	2.00
c. HD 11	2.5 MeV	2.0	25	Pb	1	1T	A	
			26	Pb	2	1T	A	
			27	11	1	1T	A	1.55
			28	11	2	1T	A	1.17
		3.0	29	Pb	1	1T	A	
			30	Pb	2	1T	A	
			31	11	1	1T	A	1.80
			32	11	2	1T	A	1.40
		4.0	33	Pb	1	1T	A	
			34	Pb	2	1T	A	
			35	11	1	1T	A	1.06
			36	11	2	1T	A	1.11
d. HS 38	150 kV	0.250	37	Pb	1	2T	A	
			38	Pb	2	2T	A	
			39	38	1	2T	A	7.50
			40	38	2	2T	A	3.00
		0.500	41	Pb	1	1T	A	
			42	Pb	2	2T	A	
			43	38	1	1T	A	4.88
			44	38	2	2T	A	7.50
		0.750	45	Pb	1	1T	A	
			46	Pb	2	1T	A	
			47	38	1	1T	A	3.07
			48	38	2	1T	A	4.71
e. HS 33	300 kV	1.0	49	Pb	1	1T	A	
			50	Pb	2	2T	A	
			51	33	1	1T	A	3.64
			52	33	2	1T	A	5.00
		1.25	53	Pb	1	1T	A	
			54	Pb	2	2T	A	
			55	33	1	1T	A	2.75
			56	33	2	1T	A	4.44
		1.50	57	Pb	1	1T	A	
			58	Pb	2	1T	A	
			59	33	1	1T	A	2.50
			60	33	2	1T	A	3.00
f. HS 31	2.5 MeV	2.0	61	Pb	1	1T	A	
			62	Pb	2	1T	A	
			63	31	1	1T	A	2.14
			64	31	2	1T	A	1.17
		3.0	65	Pb	1	1T	A	
			66	Pb	2	1T	A	
			67	31	1	1T	A	1.77
			68	31	2	1T	A	2.67
		4.0	69	Pb	1	1T	A	
			70	Pb	2	1T	A	
			71	31	1	1T	A	1.67
			72	31	2	1T	A	2.00

*Overexposed

b. The HD 13 screen was used to radiograph thicknesses from 1.0 to 1.50 inches of steel at 300 kV. The same pattern noted in the 150 kV tests is repeated at 300 kV in that the intensification factor again decreased as material thickness increased, with improvements in image resolution. All radiographs showed at least standard quality (2T) to above standard (1T).

c. The HD 11 screen was used in radiographing thicknesses from 2.0 to 4.0 inches of steel at 2.5 MeV. This screen produced the lowest I.F. values as a group which again generally decreased with increasing material thickness. Even though the I.F.'s were low, they could still be considered useful in many radiographic applications.

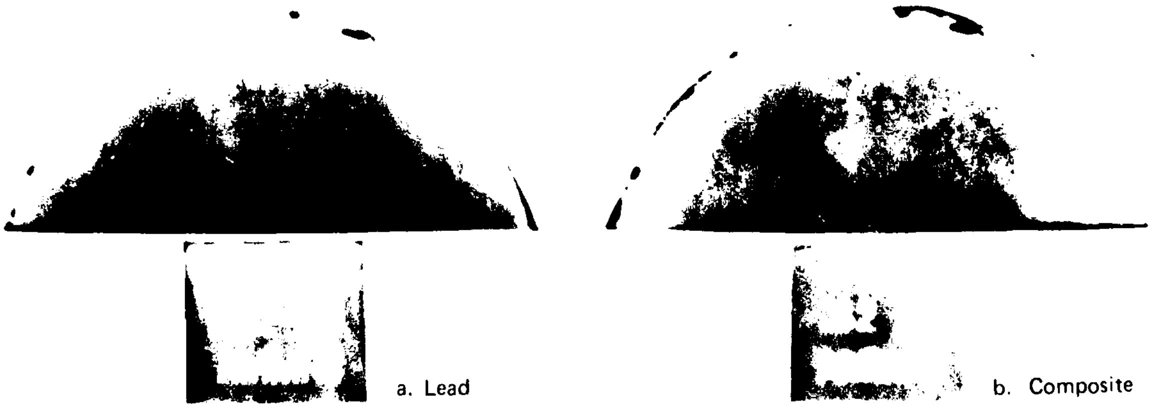
d. The HS 38 screen, used at 150 kV to radiograph the same thicknesses as the HD 18 screen, produced the highest recorded I.F. in these tests (7.5) with a decrease in I.F. as the material thickness increased. Image quality was at least standard 2T or better in most cases, which indicates that, along with its superior speed, this high speed screen is a very attractive radiographic accessory.

e. The HS 33 screen, which was used to radiograph the same thicknesses as the HD 13 screen, shows higher I.F. values at 300 kV while depicting standard to above standard image resolution. Again, the I.F. values diminish with increasing material thickness. The crack image resolution is pretty well maintained with lead as well as composite screens. Some mottling is noted with the composite screens which does not seem to affect penetrameters or crack image resolution.

f. The HS 31 screen was used at 2.5 MeV in radiographing the same thicknesses as the HD 11 screen. The HS 31 screen outperformed the HD 11 screen in I.F. values even though the image resolution for each group is above standard. This may prove to be very useful in the radiography of high density materials where scattering can be a problem. The image resolution capacity of the HS 31 screen appears to meet most code requirements for both types of films utilized. As shown in the tables, in at least half the exposures made at 2.5 MeV, there has been more than a 50% reduction in exposure times which can be significant in production radiography.

PRACTICAL APPLICATIONS

Figure 2 represents radiographs of a 0.625-inch uranium section taken at 2.5 MeV using conventional lead screens and composite screens. The left radiograph was made



a. Lead

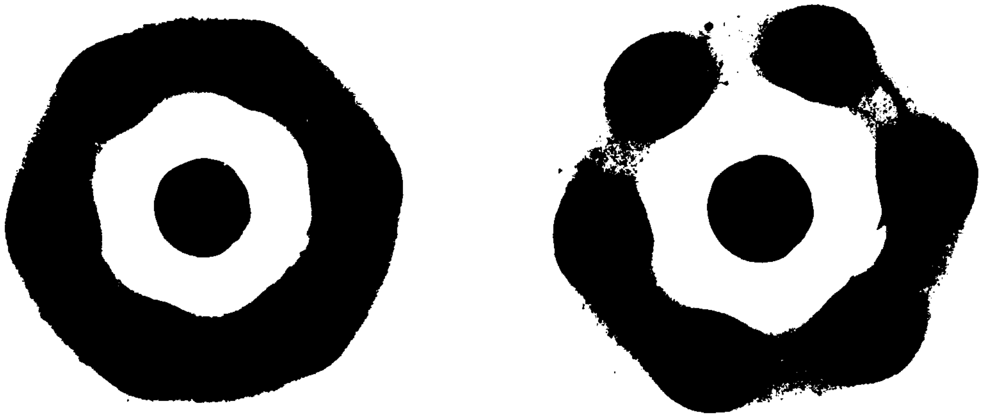
b. Composite

Figure 2. Comparison of radiographs of lead and composite screens of uranium section.

using lead screens and exposed for 2 minutes and 45 seconds. The right radiograph was made using composite screen HS 31 which was exposed for 1 minute and 30 seconds. All factors were held constant with the exception of exposure time. Image details of both radiographs appear similar, however, the composite radiograph represents a 45% reduction in exposure time, which is considerable in terms of inspection speed and X-ray tube economics.

Figure 3 represents radiographs taken of a 0.625-inch steel casting at 220 kV, again comparing lead and composite screens. The left radiograph was made using lead screens and exposed for 5 minutes. The right radiograph was made using the same composite screen HS 31, and exposed for 2 minutes. As above, all test parameters were constant other than exposure time. The exposure time using the composite screen resulted in a 60% reduction with no apparent adverse effects upon image resolution.

High speed screens were used in the radiography of tank repair welds. Initial tests indicate a reduction of at least 25% of exposure time while extending the thickness range penetrated by a 300 kV X-ray unit.



a. Lead

b. Composite

Figure 3. Comparison of radiographs of lead and composite screens of steel casting.

CONCLUSIONS

The tests conducted in this investigation have shown that fluorometallic or composite intensifying screens are a valuable and useful accessory in the field of industrial radiography. In many applications they can be used to increase radiographic inspection efficiency by reducing exposure times and possibly lowering the kilovoltages required when using conventional lead screens. Image resolution assessment was based upon the penetrameter requirements set forth in MIL-STD-453. This document outlines the radiographic quality requirements of aeronautical components. All radiographs were made using steel plates ranging in thickness from 0.250 to 4.0 inches in the 150 kV to 2.5 MeV radiation quality range. Two types of film, ASTM 1 and 2, were used throughout this investigation. It can be concluded that:

1. During this investigation, the intensification factors ranged from 1.06 to 7.5.

2. In many applications, the composite screen can allow significant reductions in radiographic speed while reducing, in some cases, kilovoltages that would be otherwise required.

3. Shorter exposure times appear to be shortened more than longer exposure times.

4. The I.F. decreases with increasing material thicknesses.

5. Image quality is generally adequate to meet most code requirements.

6. The high speed screen appears to offer more advantages than the high definition screen.

7. The composite screen represents a new amplification device for the radiographer.

RECOMMENDATIONS

It is recommended that composite screens be utilized in appropriate applications while promoting shorter exposures without loss of image resolution.

It is also recommended that, based upon the above, codes and specifications recognize the usefulness of composite screens as valid radiographic accessories by allowing their use in many production radiographic applications.

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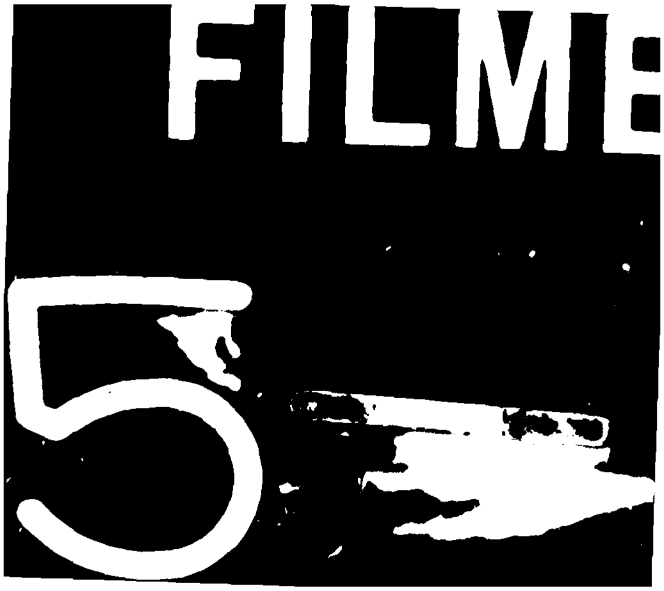
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