High-Speed NDT Imaging With High Sensitivity of Flaw Detection

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Abstract. The new KODAK INDUSTREX High-Speed HS800 Film is Kodak's fastest and most versatile film for nondestructive testing. Designed from zero as a NDT film, the new film gives excellent images with any exposure method – direct, lead screen, fluorescent screen, or fluorometallic screen. The High-Speed HS800 Film yields excellent images and provides high speed and high contrast when used with the KODAK LANEX Fast Screens. The High-Speed HS800 film combined with the efficient LANEX Fast Screens constitutes a complete Kodak film-screen solution for high-speed NDT imaging with high sensitivity of flaw detection. Designed for any high-density application where speed is an advantage, the High-Speed HS800 Film is particularly suitable for structural components such as off-shore pipelines, bridges, or concrete. For concrete inspection using an Ir^{192} source, the HS800 Film combined with the LANEX Fast Screens stretches the usable exposure thickness to 40 cms of concrete with good image quality.

The new High-Speed HS800 Film incorporates the patented KODAK T-GRAIN® Technology—just as effective in short automatic and manual processing cycles. A blue tinted base improves the psychovisual perception of radiographic contrast

- by limiting the transmitted light
- by narrowing the spectral distribution of transmitted light.

Like the other INDUSTREX Films containing T-Grain technology, the processed HS800 film uses a blue tinted base so as to produce a cold image tone on the view box. Additionally, the processed HS800 film was designed to have high gloss, resulting in better-perceived radiographs.

Designed from zero as an NDT film, the new High-Speed HS800 Film is Kodak's fastest and most versatile film in the INDUSTREX Film portfolio. The new film gives excellent images with any exposure method—direct, lead screen, fluorescent screen, or fluorometallic screen. In most instances, the contrast of the films designed for use with fluorescent or fluorometallic screens does not increase continuously with density in the usable density range and their characteristic curve displays a saturation density. R. Halmshaw [1] notes that for these so-called screen films, the film contrast reaches a maximum at a film density of ca. 1.5, and that for higher densities the contrast is markedly lower. The slope of the characteristic curve of the High-Speed HS800 Film increases continuously with density in the usable density range regardless of the type of intensifying screens. When used with fluorescent or fluorometallic screens, the new film displays high contrast throughout an extended range of optical densities, thus providing high sensitivity to flaw detection and wide exposure latitude.

Calcium tungstate ($CaWO_4$) is the oldest substance used as X-ray luminescent material (its properties were first reported by Edison in 1896). $CaWO_4$ was chosen as the luminescent material in fluorescent screens because it emits light in the blue range to which the industrial X-ray emulsion is mostly sensitive. $CaWO_4$ screens emit blue light of a continuous spectrum with a maximum at ca. 430 nm. The KODAK LANEX Fast Screens emit light in narrow lines with peaks in the blue region. They incorporate terbium-activated gadolinium oxysulfide (Gd_2O_2S:Tb) as phosphor. Table 1 compares typical screen absorption and conversion efficiency values for the $CaWO_4$ and Gd_2O_2S:Tb screens. The latter screens, incorporating a rare-earth phosphor from the lanthanide series, have significantly much higher X-ray absorption and X-ray energy conversion than $CaWO_4$ screens. Accordingly, the KODAK LANEX Fast Screens permit a greater reduction in exposure than $CaWO_4$ screens.

Table 1. Typical screen absorption and conversion efficiencies.

	Typical absorption efficiency (%) 80 kV	**Typical conversion efficiency (%)**
$CaWO_4$	21 to 38	5
Gd_2O_2S:Tb	73	18

The level of reciprocity failure for exposures to the light emitted from fluorescent and fluorometallic screens can be minimized by a suitable choice of emulsion. It is, however, not possible to give an intensification factor that applies to all exposure conditions. Using a stationary X-ray tube and 80 kV exposures, the High-Speed HS800 Film is exposing ca. 13 times faster using KODAK LANEX Fast Screens when compared to the film with no screens. Using an Ir^{192} source the High-Speed HS800 Film is exposing ca. 7 times faster using KODAK LANEX Fast Screens when compared to the film with no screens. The High-Speed HS800 Film yields excellent images and provides high speed and high contrast when used with the KODAK LANEX Fast Screens. The High-Speed HS800 Film combined with the efficient LANEX Fast Screens constitutes a completely Kodak film-screen solution for high-speed NDT imaging.

Designed for any high-density application where speed is an advantage, the High-Speed HS800 Film is particularly suitable for structural components such as off-shore pipelines, bridges, or concrete. Concrete inspection is a widespread film radiography application. Fluorescent intensifying screens can cause a large unsharpness because of the lateral spread of light in the fluorescent layer of the screen. Fluorescent intensifying screens are used in concrete inspection in order to reduce exposure times if no requirements for a spatial resolution better than 0.2 mm exists. The selection of the source depends on the wall thickness that shall be inspected. It is generally accepted that the maximum wall thickness is ca. 30 cms with Ir^{192} sources [2]. For concrete inspection using an Ir^{192} source, the HS800 Film combined with the LANEX Fast Screens stretches the usable exposure thickness to 40 cms of concrete with good image quality.

Assuming that the experimental technique (choice of radiation energy, of the geometric conditions of the setup, …) has been optimized, the fundamentals of image quality on film are film contrast, graininess, and definition.

Regardless of the type of fluorescent intensifying screens, the High-Speed HS800 Film displays high contrast throughout an extended range of optical densities and yields higher contrast than the KODAK INDUSTREX CX Film it replaced.

Over a very wide range of films, G.C. Farnell and P. Broadhead [3] have shown that the granularity obtained with a particular radiation energy is very closely proportional to the film speed. The EN 584-1:2005 Classification of film systems standard uses the ratio of the gradient G_2 and the granularity σ_D that relates directly to the signal-to-noise ratio. There is a direct linear relationship between the signal-to-noise (G_2/σ_D) ratio and speed (square root of the dose to produce a net density of 2) for all the films within the INDUSTREX Films portfolio. All the data including that for the High-Speed HS800 Film can be fitted with a single regression line ($R^2 = 0.988$).

In industrial radiography, the inverse of sharpness—unsharpness—is commonly used. Although less accurate than the MTF method, the duplex wire IQI corresponding to the EN 462-5 Image Quality of radiographs—Part 5: Image Quality Indicators (duplex wire type), determination of total image unsharpness standard can be used to evaluate image unsharpness. The largest element that is present, a pair of wires, the image of which has just merged into single form without an identifiable space between the images of the two wires, is taken as the limit of discernability. The image unsharpness is given as 2d where d is the diameter of the wire and also is the spacing between the pair of wires. Table 2 gathers the unsharpness values determined for the new High-Speed HS800 Film. These unsharpness values were found to be 0.1 mm both with lead screens and with Kyokko SMP 308 fluorometallic screens. The KODAK LANEX Fast Screens offer a dramatic speed advantage and the unsharpness is still 0.16 mm.

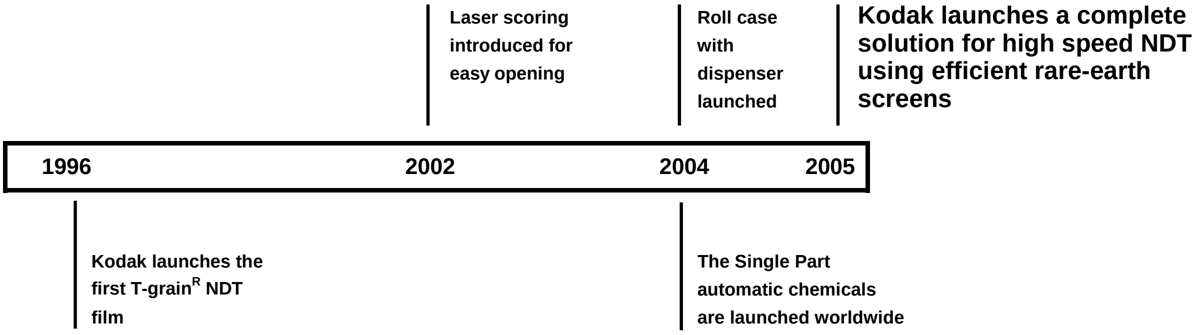
Table 2. Image unsharpness

Screens	Element #	Unsharpness (mm)	Wire diameter and spacing d (mm)
27/100/200 µm lead	13	0.1	0.05
Kyokko SMP 308	13	0.1	0.05
Kodak Lanex fast screen	11	0.16	0.08

Fluorescent intensifying screens can cause a large unsharpness because of the lateral spread of light in the fluorescent layer of the screen. The thicker the intensifying screen phosphor layer, the greater will be image unsharpness. To get any kind of good speed, the layer of $CaWO_4$ screens needs to be fairly thick and thus resolution suffers. Because of a relatively low phosphor layer thickness, the KODAK LANEX Fast Screens offer a dramatic speed advantage and comparable resolution.

Figure 1 summarizes the introduction of new film-based solutions since the launching of the first INDUSTREX Film with T-Grain technology. The High-Speed HS800 Film combined with the efficient LANEX Fast Screens constitutes a completely Kodak film-screen solution for high-speed NDT imaging with high sensitivity of flaw detection. While Kodak continues its computed radiography (CR) innovation, this new high-speed film-screen system demonstrates Kodak's long-standing commitment to providing the NDT industry with new film-based solutions.

Figure 1. Kodak's new film-based solutions



References

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[2] G.C. Farnell and P. Broadhead, J. Photographic Science, 26, 7-13, 1978.
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