III. Object-Image Relations

A radiographic image conveys information about specific compositional and geometrical properties of the object. Our aim here is to identify and characterize some of these essential relations which also are to be used in subsequent chapters.

3.1 COMPOSITIONAL AND GEOMETRICAL EFFECTS

As an introductory case, we consider an object of uniform thickness but of varying composition. The compositional variations of relevance in neutron radiography are expressed in terms of the neutron absorption cross section, $\Sigma_a$, associated with the local properties of an object. Compositional variations characterized by the neutron scattering cross section, $\Sigma_s$, are also of importance but are deferred for now because this may obscure some fundamental imaging aspects we wish to emphasize. A case of interest is depicted in Fig. 3.1a; $\Phi_c$ is the uniform neutron flux emerging from the collimator and incident on the neutron absorbing object while $\Phi_{t,1}$ and $\Phi_{t,2}$ are the transmitted uncollided neutron flux associated with each material region and which subsequently are incident on the neutron converter.

Following the analysis of Sec. 2.3, the transmitted neutron flux is determined by the isotopic composition of the material through which the beam passes. For objects of identical thickness but different composition, Fig. 3.1a, we write for the transmitted neutron flux

$$\Phi_{t,1} = \Phi_c \exp(-\Sigma_a,1 z_0) \tag{3.1a}$$
$$\Phi_{t,2} = \Phi_c \exp(-\Sigma_a,2 z_0) \tag{3.1b}$$

With each isotopically distinct material domain, we can therefore associate a converter response, $\psi_1$ and $\psi_2$, of the form suggested by Eq. (2.26), and which subsequently leads to an optical density, Sec. 2.6. That is, we have the general sequential relation

$$\Phi_t \rightarrow \psi \rightarrow D \tag{3.2}$$
where \( D \) is the experimentally measured optical density on the film. Now \( \psi \) is directly related to \( \phi_t \), Sec. 2.5, and \( D \) is related to \( \psi \) through the exposure-density variation, Sec. 2.6, and generally given by

\[
D = f(\psi t) \tag{3.3}
\]

where \( t \) is the exposure time. The optical densities corresponding to Eqs. (3.1) are therefore

\[
D_1 = f(A \exp[-\Sigma_{a,1} z_0]) \tag{3.4a}
\]
\[
D_2 = f(A \exp[-\Sigma_{a,2} z_0]) \tag{3.4b}
\]

where the constant \( A \) is the product of \( \phi_c \), \( t \) and the proportionality constant between \( \psi \) and \( \phi_t \), Eq. (2.26).

As discussed in the preceding chapter, while the relationship between the transmitted neutron flux, \( \phi_t \), and the converter response flux, \( \psi \), can be established, e.g., Eq. (2.26), and further that the exposure time \( t \) can easily be determined, it is the potential nonlinear