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Inventor(s)	Papillon; Stéphane

METHODS AND SYSTEMS FOR ALUMINUM FILTRATION DETECTION

Abstract

Various methods and systems are provided for X-ray imaging systems. In one example, a method for measuring an equivalent aluminum filtration of a tabletop comprises acquiring a single X-ray image of a tabletop and an aluminum filtration scale using a detector; identifying a brightness of the tabletop and a brightness of the aluminum filtration scale in the single X-ray image; computing an aluminum equivalence of the tabletop, converting the brightness of the aluminum filtration scale to an air KERMA of the aluminum filtration scale and converting the aluminum equivalence of the tabletop to an air KERMA of the tabletop; and comparing the air KERMA of the tabletop to the air KERMA of the aluminum filtration scale to identify an air equivalent aluminum filtration of the tabletop.

Inventors: **Papillon; Stéphane (Morêt Loing et Orvanne, Seine et Marne, FR)**

Applicant: **GE Precision Healthcare LLC** (Waukesha, WI)

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Background/Summary

FIELD

[0001] Embodiments of the subject matter disclosed herein relate to medical imaging systems, and more particularly, to radiographic imaging systems.

BACKGROUND

[0002] Radiographic imaging systems may be used in various applications, including medical and industrial applications. In a medical environment, a radiographic imaging device may provide a non-invasive means of imaging tissue and bone of a patient. The radiographic imaging device may have the capability of capturing multiple images at designated intervals and displaying the images in a sequence to create a single image of the object being examined.

[0003] The radiographic imaging device may be an X-ray imaging device comprised of a C-arm coupled to a base unit. The C-arm may include an X-ray source positioned at one end of the arm and a detector positioned at another end of the arm. A clearance may be provided between the X-ray source and the detector to receive an object, such as a portion of the patient's body, which may be irradiated with radiation from the X-ray source. At least a portion of the patient's body may be positioned on a tabletop of the X-ray imaging device, which may be at least partially positioned in the clearance of the C-arm between the X-ray source and the detector. Upon irradiating the object, the X-ray radiation penetrates through the object and the tabletop, and is captured by the detector. By penetrating the object and the tabletop placed between the X-ray source and detector, the X-rays enable an image of the object to be captured and relayed to the display monitor, where the image may be displayed or stored and retrieved later. The image of the object may further include the portion of the tabletop positioned between the X-ray source and the detector.

BRIEF DESCRIPTION

[0004] In one example, a method for measuring an equivalent aluminum filtration of a tabletop comprising: acquiring a single X-ray image of a tabletop and an aluminum filtration scale using a detector; identifying a brightness of the tabletop and a brightness of the aluminum filtration scale in the single X-ray image; computing an aluminum equivalence of the tabletop, converting the brightness of the aluminum filtration scale to an air kinetic energy released per unit mass (KERMA) of the aluminum filtration scale; converting the aluminum equivalence of the tabletop to an air KERMA of the tabletop; and comparing the air KERMA of the tabletop to the air KERMA of the aluminum filtration scale to identify an air equivalent aluminum filtration of the tabletop. The tabletop may be a tabletop of a patient bed or other surface that a patient or imaging subject is positioned on. For example, the tabletop may be a patient bed of a medical X-ray imaging system.

[0005] The method for measuring the equivalent aluminum filtration of the tabletop may be executed using an X-ray imaging system comprising an X-ray tube, a detector, and an aluminum filtration measurement tool having a tabletop window and the aluminum filtration scale. The X-ray imaging system may be configured for manufacturing and quality control purposes, and not for medical imaging of a patient.

[0006] It should be understood that the brief description above is provided to introduce in simplified form a selection of concepts that are further described in the detailed description. It is not meant to identify key or essential features of the claimed subject matter, the scope of which is defined uniquely by the claims that follow the detailed description. Furthermore, the claimed subject matter is not limited to implementations that solve any disadvantages noted above or in any part of this disclosure.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The present invention will be better understood from reading the following description of non-limiting embodiments, with reference to the attached drawings, wherein below:

[0008] FIG. **1** shows an example medical imaging system including a C-arm, according to an embodiment;

[0009] FIG. **2** shows an example X-ray imaging system, according to an embodiment;

[0010] FIGS. **3**A-**3**B show views of an example aluminum filtration measurement tool, including an aluminum filtration scale, according to an embodiment;

[0011] FIG. **4** shows an example image captured of a tabletop and of the aluminum filtration measurement tool of FIGS. **3**A-**3**B by the X-ray imaging system of FIG. **2**;

[0012] FIG. **5** shows a first series of graphs illustrating application of conversion factors (CF) to cesium iodide (CsI) scintillator profiles of the aluminum filtration scale and the tabletop of FIG. **4** to compute air KERMA profiles thereof, according to an embodiment;

[0013] FIG. **6** shows a graph with plots illustrating tabletop CsI scatter correction, according to an embodiment;

[0014] FIG. **7** shows a graph with plots illustrating an effect of a scatter point spread function (ScPCF) that provides a scattered signal shape over an irradiated area of the tabletop, according to an embodiment;

[0015] FIG. **8** shows a graph with plots illustrating relative CF for aluminum or equivalent aluminum thicknesses of the aluminum filtration scale and the tabletop, according to an embodiment;

[0016] FIG. **9** shows a graph with plots illustrating air KERMA vs aluminum thickness filtration profiles of the aluminum filtration scale and the tabletop, according to an embodiment;

[0017] FIGS. **10**A-**10**B show a flow chart of a method for measuring an equivalent aluminum filtration of a tabletop; and

[0018] FIG. **11** shows a flow chart of a method for performing an iterative cleanup of individual pixels of the tabletop window in an X-ray image.

DETAILED DESCRIPTION

[0019] The following description relates to various embodiments for identifying an aluminum equivalence filtration measurement of a tabletop. The tabletop may be a surface of a medical imaging system, such as the medical imaging system of FIG. **1**, on which an imaging subject is positioned. Irradiating beams of the medical imaging system of FIG. **1** may pass through the imaging subject and be filtered by the tabletop on a path to a detector of the medical imaging system. The aluminum equivalence filtration measurement of the tabletop of FIG. **1** may provide a measurement of the amount of filtration provided by the tabletop. The aluminum equivalence filtration measurement of the tabletop may be performed using a non-medical X-ray imaging system, an example of which is shown in FIG. **2**. An example aluminum filtration tool, including a tabletop window and an aluminum filtration scale, is shown in FIGS. **3**A-**3**B. The aluminum filtration tool may be positioned on the tabletop and a detector of the non-medical X-ray imaging system of FIG. **2**, and the tabletop and the aluminum filtration scale may be simultaneously exposed to a single X-ray beam to capture an X-ray image, an example of which is shown in FIG. **4**. Information from the X-ray image of FIG. **4** may be used to determine the aluminum equivalence filtration measurement of the tabletop, as described with respect to FIGS. **5-9**. FIG. **5** shows a first series of graphs illustrating application of conversion factors (CF) to cesium iodide (CsI) scintillator profiles of the aluminum filtration scale and the tabletop of FIG. **4** to compute air KERMA profiles thereof. FIG. **6** shows a graph with plots illustrating tabletop CsI scatter correction. FIG. **7** shows a graph with plots illustrating an effect of a scatter point spread function (ScPCF) that provides a scattered signal shape over an irradiated area of the tabletop. FIG. **8** shows a graph with plots illustrating relative CFs for aluminum or equivalent aluminum thicknesses of the aluminum filtration scale and the tabletop. FIG. **9** shows a graph with plots illustrating air KERMA vs aluminum thickness filtration profiles of the aluminum filtration scale and the tabletop. FIGS. **10**A-**10**B show a flow chart of a method for measuring an equivalent aluminum filtration of a tabletop. FIG. **11** provides further detail of the method **1000** and shows a method **1100** for performing an iterative cleanup of individual pixels of the tabletop window in the X-ray image. FIGS. **2**-**3**B are shown approximately to scale.

[0020] Referring to FIG. **1**, an imaging system **100** including a C-arm **102** (which may be referred to herein as a C-shaped gantry) is schematically shown. Imaging system **100** may be referred to herein as a medical imaging system and/or C-arm imaging system. The imaging system **100** includes a radiation source, and in the examples described herein, the radiation source is an X-ray unit **108** (which may be referred to herein as an X-ray tube) positioned opposite to detector **130** (which may be referred to herein as an X-ray detector) and configured to emit X-ray radiation. In other examples, the radiation source may be configured to emit a different type of radiation for imaging (e.g., imaging a subject, such as patient **134**), such as gamma rays, and the detector (e.g., X-ray detector **130**) may be configured to detect the radiation emitted by the radiation source (e.g., X-ray beam **132**). The imaging system **100** additionally includes base unit **105** supporting imaging system **100** on ground surface **190** on which the imaging system **100** sits (e.g., via base **122** supported by wheel **124**, wheel **126**, etc.).

[0021] The C-arm **102** includes a C-shaped portion **103** connected to an extended portion **107**, with the extended portion **107** rotatably coupled to the base unit **105**. The detector **130** is coupled to the C-shaped portion **103** at a first end **150** of the C-shaped portion **103**, and the X-ray unit **108** is coupled to the C-shaped portion **103** at an opposing end, such as a second end **152** of the C-shaped portion **103**. As an example, the C-arm **102** may be configured to rotate at least 180 degrees in opposing directions relative to the base unit **105**. The C-arm **102** is rotatable about at least a rotational axis **164** and may additionally rotate about axis **167**. The C-shaped portion **103** may be rotated as described above in order to adjust the X-ray unit **108** and detector **130** (positioned on opposite ends of the C-shaped portion of the C-arm **102** along axis **166**, where axis **166** intersects rotational axis **164** and extends radially relative to rotational axis **164**) through a plurality of positions.

[0022] During an imaging operation (e.g., a scan), a portion of a body of a patient placed in an opening formed between the X-ray unit **108** and detector **130** may be irradiated with radiation from the X-ray unit **108**. For example, patient **134** may be supported by a patient support table **136**, with the patient support table **136** including a support surface **138** and base **140**, and may be arranged between the X-ray unit **108** and the detector **130**. The X-ray unit **108** includes an X-ray tube insert **109** and X-ray radiation generated by the X-ray tube insert **109** may emit from the X-ray unit **108**. The radiation may penetrate the portion of the body arranged to be irradiated and may travel to the detector **130** where the radiation is captured (e.g., intercepted by a detector surface **113** of the detector **130**). By penetrating the portion of the body placed between the X-ray unit **108** and detector **130**, an image of the body is captured and relayed to an electronic controller **120** of the imaging system **100** (e.g., via an electrical connection line, such as electrically conductive cable **161**). The image may be displayed via display device **118**. Images of the subject acquired by the imaging system **100** via the X-ray unit **108** and the detector **130** as described above may be referred to herein as projection images and/or scan projection images.

[0023] The base unit **105** may include the electronic controller (e.g., a control and computing unit) that processes instructions or commands sent from the user input devices during operation of the imaging system **100**. The base unit **105** may also include an internal power source (not shown) that provides electrical power to operate the imaging system **100**. Alternatively, the base unit **105** may be connected to an external electrical power source to power the imaging system **100**. A plurality of connection lines (e.g., electrical cables, such as electrically conductive cable **161**) may be provided to transmit electrical power, instructions, and/or data between the X-ray unit **108**, detector **130**, and the control and computing unit. The plurality of connection lines may transmit electrical power from the electrical power source (e.g., internal and/or external source) to the X-ray unit **108** and detector **130**.

[0024] The C-arm **102** may be adjusted to a plurality of different positions by rotation of the C-shaped portion **103** of the C-arm **102**. For example, in an initial, first position shown by FIG. **1**, the detector **130** may be positioned vertically above the X-ray unit **108** relative to a ground surface **190** on which the imaging system **100** sits, with axis **166** arranged normal to the ground surface **190** intersecting a midpoint of each of an outlet **111** of X-ray unit **108** and detector surface **113** of detector **130**. The C-arm **102** may be adjusted from the first position to a different, second position by rotating the C-shaped portion **103**. In one example, the second position may be a position in which the X-ray unit **108** and detector **130** are rotated 180 degrees together relative to the first position, such that the X-ray unit **108** is positioned vertically above the detector **130**, with axis **166** intersecting the midpoint of the outlet **111** of the X-ray unit **108** and the midpoint of the detector surface **113** of the detector **130**. When adjusted to the second position, the X-ray unit **108** may be positioned vertically above the rotational axis **164** of the C-shaped portion **103** of the C-arm **102**, and the detector **130** may be positioned vertically below the rotational axis **164**. Different rotational positions of the C-arm **102** are possible.

[0025] During irradiation of an imaging subject (e.g., the patient **134**), radiation emitted by the radiation source of a medical imaging system (e.g., the imaging system **100**) may pass through the imaging subject and through a tabletop (e.g., the support surface **138**) of the imaging system before being received by the detector (e.g., the detector **130**). In passing through the tabletop, characteristics of the irradiating beams (e.g., the X-ray beam **132**), such as a beam strength, may be changed by material properties of the tabletop. For example, the irradiating beam may experience inherent filtration when passing through the tabletop on the path to the detector. Inherent filtration of the irradiating beam by the tabletop may remove lower energy beams from the irradiating beam by absorbing lower energy photons of the irradiating beam into the tabletop. Filtration of the irradiating beam by the tabletop may affect measurements by the detector. For example, an image generated from image data captured by the detector may have low contrast, low sharpness, and/or low brightness, depending on an amount of filtration by the tabletop, compared to an image generated from non-filtered irradiating beam image data. It is desirable to characterize material properties of the tabletop, and use information about the material properties to adjust measurements captured by the detector.

[0026] Spectral filtration of X-ray beams is used to supplement filtration in some irradiation imaging systems. For example, an aluminum filter having a known thickness may be positioned between an irradiating source and a detector. Filtration of an X-ray beam emitted by the irradiating source is increased (e.g., energy of the X-ray beam that reaches the detector is decreased) with an increase in the thickness of the aluminum filter. Filtration of an irradiating beam by a tabletop, which may or may not include aluminum, may be modeled by comparing tabletop filtration to aluminum filtration. For example, an aluminum equivalent filtration measurement of the tabletop may be identified and corresponding adjustments may be made to measurements captured by the detector to achieve accurate measurements and imaging data. Conventionally, an aluminum equivalent filtration measurement is performed by human interpretation of a developed radiographic film. Radiographic film technology is progressively being used less often in diagnostic X-ray, and is expected to become obsolete. Additionally, a time to develop film may be undesirably long compared to a digital X-ray image, which may be available less than one minute after X-ray exposure. Thus, a method is desired for identifying an aluminum equivalence filtration measurement of a tabletop that is more accurate, faster, and less resource intensive, compared to conventional radiographic methods.

[0027] Described herein is a method for aluminum filtration equivalence measurement. The method comprises acquiring a single X-ray image of a tabletop and an aluminum filtration scale captured using a detector, identifying a brightness of the tabletop and a brightness of the aluminum filtration scale in the single X-ray image, computing an aluminum equivalence of the tabletop, converting the brightness of the aluminum filtration scale to an air KERMA of the aluminum filtration scale, converting the aluminum equivalence of the tabletop to an air KERMA of the tabletop, and comparing the air KERMA of the tabletop to the air KERMA of the aluminum filtration scale to identify an air equivalent aluminum filtration of the tabletop. The method further includes performing scatter correction on the brightness of the aluminum filtration scale and on the aluminum equivalence of the tabletop.

[0028] FIG. **2** shows an example X-ray imaging system **200**. The imaging system **200** may be an embodiment of an X-ray imaging system, and may thus include one or more of the same elements as the medical imaging system **100** of FIG. **1**. However, where the medical imaging system **100** is configured to capture medical X-ray images of imaging subjects (e.g., a patient), the X-ray imaging system **200** is configured as a manufacturing and quality control tool. For example, the X-ray imaging system **200** may be used to capture X-ray images of inanimate objects, such as a tabletop and/or a tabletop sample, and assess material qualities of the tabletop. An axis system **299** is provided in FIGS. **2-4** for reference. The y-axis may be a vertical axis (e.g., parallel to a gravitational axis), the x-axis may be a lateral axis (e.g., horizontal axis), and the z-axis may be a longitudinal axis, in one example. However, the axes may have other orientations, in other examples.

[0029] The imaging system **200** is configured with a vertical X-ray tube **204** and a radiology digital X-ray detector **206**, herein also “the detector”. In some embodiments, the imaging system **200** is further configured with an inclined X-ray tube **202**. The vertical X-ray tube **204** and the inclined X-ray tube **202** may each be mounted on one of two crossbars **214**, **212** of a frame **210** of the imaging system **200**. Each of the vertical X-ray tube **204** and the inclined X-ray tube **202** may be moveable along a respective crossbar of the two crossbars **214**, **212**. For example, the vertical X-ray tube **204** may be repositioned (e.g., moved/slid) on the crossbar **214** along the x-axis to assist in focusing an X-ray beam on a desired region of the detector **206** (and an object positioned thereon for imaging). In further embodiments, one or more of the vertical X-ray tube **204** and the inclined X-ray tube **202** may be moveable in three dimensions, for example, as enabled by adjustable elements of the two crossbars **214**, **212**, and/or the frame **210** of the imaging system **200**. In some embodiments, the vertical X-ray tube **204** may be rotatable (e.g., by 90 degrees) to provide a constant beam quality for comparing regions of interest in an aluminum scale and tabletop window, as further described with respect to FIGS. **3**A-**10**B. Additionally, a position of the detector **206** may be adjustable with respect to one or more of the x-axis, the y-axis, and the z-axis. The X-ray imaging system **200** may be mobile, for example, the frame **210** of the X-ray imaging system **200** may be configured with wheels (not shown in FIG. **2**) that enable the imaging system **200** to be moved about a space, such as throughout a manufacturing environment.

[0030] The vertical X-ray tube **204** is configured to direct irradiating X-ray beams in a direction orthogonal to the detector **206** during an imaging operation (e.g., an imaging scan). As further described herein with respect to FIGS. **3**A-**4** and **10**A-**10**B, the X-ray beam may penetrate a portion of a tabletop and an aluminum filtration measurement tool positioned between the vertical X-ray tube **204** and the detector **206**. Penetrating X-ray beams travel to the detector **206**, where the radiation is captured by the detector **206**. The detector **206** may be any type of X-ray detector. For example, the radiology digital X-ray detector **206** may comprise a flat panel (e.g., in the x-z plane) and a cesium iodide (CsI) scintillator, for example. The CsI scintillator of the detector **206** is configured to receive X-ray beams (e.g., from the vertical X-ray tube **204**) and convert the X-ray beams to visible light. The detector **206** may detect and capture the visible light as image data. In other examples, the detector **206** may include a different type of scintillator, or may not include a scintillator-like direct conversion detector. The method is described herein with respect to a CsI scintillator detector, and other types of X-ray detectors may be used as the detector **206** without departing from the scope of the present disclosure.

[0031] The imaging system **200** is further configured with a controller **216**, which may be an embodiment of the electronic controller **120** of FIG. **1**. The controller **216** is communicably coupled to the vertical X-ray tube **204**, the inclined X-ray tube **202**, the detector **206**, and other elements of the imaging system **200** via wired or wireless connections. For example, the controller **216** may control one or more motors housed in a base **220** of the imaging system **200**, where the one or more motors are configured to adjust a position of the detector **206**, as further described herein. The controller **216** may further control emission of irradiating beams by the inclined X-ray tube **202** and/or by the vertical X-ray tube **204**. The controller **216** includes a processor **240** configured to execute machine-readable instructions stored in a non-transitory memory **238** of the controller **216**. The processor **240** may be single core or multi-core, and the programs executed by the processor **240** may be configured for parallel or distributed processing. In some embodiments, the processor **240** may optionally include individual components that are distributed throughout two or more devices, which may be remotely located and/or configured for coordinated processing. In some embodiments, one or more aspects of the processor **240** may be virtualized and executed by remotely-accessible networked computing devices configured in a cloud computing configuration. In some embodiments, the processor **240** may include other electronic components capable of carrying out processing functions, such as a digital signal processor, a field-programmable gate array (FPGA), or a graphics board. In some embodiments, the processor **240** may include multiple electronic components capable of carrying out processing functions. For example, the processor **240** may include two or more electronic components selected from a plurality of possible electronic components, including a central processor, a digital signal processor, a field-programmable gate array, and a graphics board. In still further embodiments, the processor **240** may be configured as a graphical processing unit (GPU), including parallel computing architecture and parallel processing capabilities. In some embodiments, the controller **216** may be integrated in the imaging system **200** (e.g., housed in the base **220**). In other embodiments, the controller **216** may be part of a computing device communicably coupled to the imaging system **200**.

[0032] As further described herein with respect to FIGS. **3**A-**10**B, the controller **216** may execute instructions for carrying out a method for aluminum equivalent filtration measurement, based on instructions stored on a memory of the controller **216** and in conjunction with signals received from sensors of the imaging system **200**, such as the radiology digital X-ray detector **206**. For example, the controller **216** may receive image data from the detector **206** and generate an X-ray image from the image data.

[0033] As further described herein, a tabletop and/or a tabletop sample (not shown in FIG. **2**) may be positioned on the radiology digital X-ray detector **206**, and the method described herein for aluminum equivalent filtration measurement may be executed to measure an aluminum equivalent thickness of the tabletop. Briefly, a position of the vertical X-ray tube **204** and/or the detector **206** may be adjusted such that X-ray beams output by the vertical X-ray tubes **204** may travel to and be detected by the detector **206**. The vertical X-ray tube **204** may output irradiating X-ray beams, and the irradiating X-ray beams may pass through and be filtered by the tabletop (not shown in FIG. **2**). In the embodiment described herein, the vertical X-ray tube **204** is configured to emit an irradiating X-ray beam that meets Title 21 of the Code of Federal Regulations (21 CFR). For example, the vertical X-ray tube **204** may, with or without addition of supplemental irradiation beam filters coupled to the vertical X-ray tube **204**, emit irradiating beams with a half value layer (HVL) greater than 3.6 millimeters (mm) for a 100 kilovolts peak of the X-ray beam. Further details regarding measuring an aluminum equivalent thickness of the tabletop using the X-ray imaging system **200** of FIG. **2** are described with respect to FIGS. **3**A-**4**.

[0034] Turning to FIGS. **3**A and **3**B, illustrations **300** are shown of an aluminum filtration measurement tool **350**. The illustrations **300** of FIGS. **3**A-**3**B include a top-down view **302**, a side view **304**, a first perspective view **306**, and a second perspective view **308** for visualization of the tool **350**. The aluminum filtration measurement tool **350** comprises a first planar surface **310** having a tabletop window **354** extending through a thickness **364** of the first planar surface **310**, and a second planar surface **312** having an aluminum scale window **356** extending through a thickness **364** of the second planar surface **312**. The thickness **364** of each of the first planar surface **310** and the second planar surface **312** may be equal, in some embodiments. For example, the thickness **364** of each of the first planar surface **310** and the second planar surface **312** may be 3 mm. The second planar surface **312** is offset from and coupled to the first planar surface **310** by a vertical wall **358** that is perpendicular to the first planar surface **310** and to the second planar surface **312**. For example, the vertical wall **358** is coupled to the first planar surface **310** along a first edge **322** and is coupled to the second planar surface **312** along a second edge **324**. The first edge **322** and the second edge **324** are thus in vertical alignment. The first planar surface **310** is therefore elevated above the second planar surface **312** by a height **366** of the vertical wall **358**. Each of the first planar surface **310** and the second planar surface **312** extend away from the first edge **322** and the second edge **324**, respectively, in opposite directions. A thickness **364** of the vertical wall **358** may be equal to the thickness **364** of the first planar surface **310** and the second planar surface **312**, in some embodiments. The first planar surface **310**, the second planar surface **312**, and the vertical wall **358** may be formed of lead and/or a mixture of lead and carbon. The aluminum filtration measurement tool **350** further comprises an aluminum filtration scale **352** positioned in the aluminum scale window **356**. The aluminum filtration scale **352** comprises a series of aluminum steps arranged in parallel along a length **320** of the aluminum filtration scale **352**. Each step of the series of aluminum steps has a different aluminum thickness compared to other steps of the series of aluminum steps. For example, a first step **326** of the series of steps may have a first thickness, a second step **328** of the series of steps may have a second thickness, less than the first thickness, a third step **330** of the series of steps may have a third thickness, less than the second thickness, and so on. In embodiments where the aluminum filtration scale **352** has eight steps in the series of steps, the first thickness of the first step **326** may be 1 mm, the second thickness of the second step **328** may be 0.9 mm, the third thickness of the third step **330** may be 0.85 mm, a fourth thickness of a fourth step may be 0.8 mm, a fifth thickness of a fifth step may be 0.7 mm, a sixth thickness of a sixth step may be 0.6 mm, a seventh thickness of a seventh step may be 0.5 mm, and an eighth thickness of an eighth step may be 0.4 mm. In some embodiments, a last step of the series of steps (e.g., a sixth step **332** in the embodiment shown in FIGS. **3**A-**3**B) may include a smallest feasible thickness, where the thickness of the sixth step **332** provides little to no filtration.

[0035] The tabletop window **354** and the aluminum scale window **356** may be approximately the same size and shape, and may be positioned side-by-side, with portions of the first planar surface **310**, the vertical wall **358**, and the second planar surface **312** therebetween. Irradiating beams may pass through the aluminum filtration measurement tool **350** at the tabletop window **354**. As there is no material positioned in the tabletop window **354**, irradiating beams may pass through the tabletop window **354** without being filtered. Irradiating beams may additionally pass through the aluminum filtration measurement tool **350** at the aluminum filtration scale **352** positioned in the aluminum scale window **356**. The irradiating beams that pass through the aluminum filtration scale **352** may be filtered by different amounts. For example, irradiating beams that pass through a greater aluminum thickness (e.g., the thickness **364** of the first step **326**) may be more filtered than irradiating beams that pass through a lesser aluminum thickness (e.g., the thickness of the third step **330**) of the aluminum filtration scale **352**. The first planar surface **310**, the second planar surface **312**, and the vertical wall **358** are configured to block transmission of irradiating beams through the aluminum filtration measurement tool **350**. For example, the vertical wall **358** may prevent cross-scattered radiation between the tabletop **362** and sides of the aluminum filtration scale **352**.

[0036] The aluminum filtration measurement tool **350** may be used with an X-ray imaging system (e.g., the X-ray imaging system **200** of FIG. **2**) to measure an equivalent aluminum filtration of the tabletop **362**. The tabletop **362** may be a support surface on which an imaging subject is positioned for X-ray imaging (e.g., the support surface **138** of FIG. **1**). The tabletop **362** may be formed of, for example, a foam material positioned between two carbon-fiber layers. In some embodiments, the tabletop **362** measured using the aluminum filtration measurement tool **350** may be a sample and/or a section of material used to form support surfaces. The following description of FIGS. **3**A and **3**B refers to and includes elements of the X-ray imaging system **200** of FIG. **2**, though it is to be understood that the aluminum filtration measurement tool **350** may be used with other X-ray imaging systems in other embodiments.

[0037] The tabletop **362** (e.g., the tabletop sample or section) may be positioned on the detector **206** of the X-ray imaging system **200**, and the aluminum filtration measurement tool **350** may be positioned to at least partially cover the tabletop **362**. For example, the first planar surface **310** is in face-sharing contact with at least a portion of the tabletop **362**, and a portion of the tabletop **362** is exposed to air at the tabletop window **354**. The second planar surface **312** is in face-sharing contact with the detector **206**. In some embodiments, the vertical wall **358** may be at least partially in contact with the tabletop **362**. The tabletop **362** and the aluminum filtration measurement tool **350** are positioned with respect to an X-ray tube (e.g., the vertical X-ray tube **204** of FIG. **2**) and the detector **206** such that irradiating beams **360** emitted by the X-ray tube may fully encompass the aluminum filtration measurement tool **350**. The irradiating beams **360** may at least partially encompass the tabletop **362** and the detector **206**. Further, the X-ray tube is oriented such that a cathode-anode axis **316** of the X-ray tube is orthogonal to a center line **314** of the tabletop window **354** and the aluminum scale window **356**. In this way, positioning of the aluminum filtration measurement tool **350** may block irradiating beams from surfaces of the tabletop **362** other than a portion of the tabletop **362** exposed by the tabletop window **354**.

[0038] As described with respect to FIG. **2**, the detector **206** may include a CsI scintillator that converts captured irradiating beams to light, which is processed by the controller of the X-ray imaging system to generate an X-ray image. Turning briefly to FIG. **4**, the figure shows an example annotated X-ray image **400** captured of the aluminum filtration measurement tool **350** and the tabletop **362**. Elements of the annotated X-ray image **400** that are annotated (e.g., are not captured by the detector **206** and are added to the X-ray image by a post processing method) are noted. The annotated X-ray image **400** includes annotation of a first region **402** that encompasses the tabletop window **354** and a portion of the tabletop **362** visible through the tabletop window **354**. The annotated X-ray image **400** further includes annotation of a second region **404** that encompasses the aluminum scale window **356** and the aluminum filtration scale **352** positioned in the aluminum scale window **356**.

[0039] As described above, the aluminum filtration scale **352** includes the series of steps having different aluminum thicknesses, and each aluminum thickness may filter the X-ray beams by a different amount. Thus, in an X-ray image captured by the detector **206**, each step of the series of aluminum steps may have a different brightness. In the annotated X-ray image **400**, an image of the aluminum filtration scale **352** shows a gradient of X-ray beam filtration performed by the aluminum filtration scale **352**. For example, the second region **404** shows detected X-ray beams that have been filtered by the first step **326** having the first thickness, the second step **328** having the second thickness, and so on. The thickness of each step of the series of steps decreases in a direction of an arrow **406**. Consequently, as the thickness decreases, filtering of the X-ray beam by the step decreases. X-ray beams filtered by the first step **326** are subject to the most filtering (e.g., by the first, greatest thickness), and thus a brightness of the image of the first step **326** is relatively low. X-ray beams filtered by the second step **328** are subject to less filtering than X-ray beams filtered by the first step **326**, and a brightness of the image of the second step **328** is greater than a brightness of the image of the first step **326**. In embodiments where the thickness of the sixth step **332** provides little to no filtration of X-ray beams, the brightness of the approximately equivalent to brightness of an unfiltered surface. As shown in the first region **402**, the image of the tabletop **362** captured in the tabletop window **354** may have a single brightness for the entirety of the tabletop **362**.

[0040] FIG. **5** shows a first series of graphs **500** illustrating application of conversion factors (CF) to cesium iodide (CsI) scintillator profiles of the aluminum filtration scale **352** and the tabletop **362** to compute air KERMA profiles thereof. A first graph **510** shows plots of CsI detection profiles of an aluminum filtration scale and of a tabletop, where the CsI detection profiles have not had conversion factors applied thereto. The first graph **510** includes pixel values along the x-axis, which indicates a position on an X-ray image (e.g., the annotated X-ray image **400** of FIG. **4**), and a number of photons detected along the y-axis, which indicates a brightness of the X-ray image. Thus, the first graph **510** illustrates relative brightness of the X-ray image in different regions of the tabletop and of the aluminum filtration scale. A second graph **520** shows plots of relative conversion factors for each of the CsI detection profile of the aluminum filtration scale and the CsI detection profile of the tabletop. A third graph **530** shows plots of CsI detection profiles of an aluminum filtration scale and of a tabletop, where the CsI detection profiles (e.g., shown in the second graph **520**) have had conversion factors applied thereto.

[0041] As described above, the CsI scintillator of the detector **206** is configured to convert radiation to visible light. A CsI detection profile may be generated for each of the tabletop **362** and the aluminum filtration scale **352** using visible light image data captured by the detector **206** via the CsI scintillator. The CsI detection profile may illustrate a relative brightness of the respective image region (e.g., the tabletop **362** and the aluminum filtration scale **352** described with respect to FIG. **4**). A CsI detection profile of the tabletop may be compared to a CsI detection profile of the aluminum filtration scale to compute a CsI aluminum equivalence of the tabletop.

[0042] The first graph **510** shows a first plot **502** illustrating a CsI detection profile of the tabletop **362**, and a second plot **504** illustrating a CsI detection profile of the aluminum filtration scale **352**. As described above, the pixel value is plotted along the x-axis. The pixel value may be equivalent to a longitudinal position in the X-ray image. For example, with reference to FIG. **4**, the pixel value may be a position in the annotated X-ray image **400** along the z-axis. A lower pixel value may be a position closer to a first side **424** of the annotated X-ray image **400**, and a higher pixel value may be a position closer to a second side **426** of the annotated X-ray image **400**, opposite the first side **424**. For example, a first region **508** encompassing pixel values between 200 and 300 corresponds to a first region **428** of the annotated X-ray image **400** (e.g., including the sixth step **332** and a fifth step **334** of the aluminum filtration scale **352**, and a corresponding region of the tabletop **362**). A second region **518** encompassing pixel values between 300 and 400 corresponds to a second region **430** of the annotated X-ray image **400** (e.g., including the fifth step **334** and a fourth step **336** of the aluminum filtration scale **352**, and a corresponding region of the tabletop **362**).

[0043] The second plot **504** includes a series of stepwise increases in CsI profile of the aluminum filtration scale **352** that correspond to each step of the series of aluminum steps. For example, a first plateau **506** of the second plot **504** between approximately 160 pixels and 270 pixels illustrates a quality of the X-ray beam detected by the CsI scintillator in the first region of the first step **326**, where the first step **326** has the first thickness. The first thickness may be equal to 1.0 mm, such as in the embodiment described herein. As the thickness decreases in the aluminum filtration scale **352**, the brightness (e.g., the CsI value of the second plot **504**) increases. The first plot **502** has a dome-like shape, which is also partially visible in the second plot **504** on either end of the series of stepwise increases. CsI values of the first plot **502** between approximately 200 pixels and 800 pixels are equal to approximately 240 photons, illustrating a near uniform brightness for the tabletop **362**. The dome-like shape of each of the first plot **502** and the second plot **504** may be an effect of scattered radiation. Correction of the CsI scintillator detection profiles of each of the tabletop **362** and of the aluminum filtration scale **352** may include scatter correction, as further described herein.

[0044] The first plot **502** and the second plot **504** of the first graph **510** intersect between 100 and 200 pixels, which is in the region of the first step **326** of the aluminum filtration scale **352**. Therefore, an initial observation may be that the CsI aluminum equivalence of the tabletop is equal to the thickness of the first step **326** of the aluminum filtration scale **352**. The CsI detection profile of the tabletop **362** and the CsI detection profile of the aluminum filtration scale **352** are not directly comparable however, as a CsI scintillator response may vary among materials through which the irradiating beam is transmitted prior to reaching the detector **206**. When the X-ray beam passes through each step of the series of steps of the aluminum filtration scale **352** (e.g., transmission of the X-ray beam through aluminum), a quality of the X-ray beam is changed, which affects how the X-ray beam is received by the detector **206**. The quality of the X-ray beam is also changed when the X-ray beam passes through the tabletop **362**, due to attenuation of the X-ray beam by the tabletop **362**. Additionally, the CsI scintillator may not operate as a dosimeter, that is, the CsI scintillator may not directly measure a dose of ionizing radiation absorbed by the tabletop **362** or by each step of the series of steps of the aluminum filtration scale **352**. Therefore, measuring an equivalent aluminum filtration of the tabletop **362** demands correction of each of the CsI detection profile of the tabletop **362** and the CsI detection profile of the aluminum filtration scale **352**.

[0045] The type of material that the irradiating beams pass through on the path to the detector may change the quality of the irradiating beams differently. Therefore, correcting each of the CsI detection profiles for the tabletop **362** (e.g., formed of foam and carbon fiber) and for the aluminum filtration scale **352** (e.g., formed of aluminum) includes applying conversion factors having different values to each CsI detection profile. The second graph **520** of the first series of graphs **500** shows a first series of data points **512** illustrating conversion factor values for different thicknesses of carbon, and a second series of data points **514** illustrating conversion factor values for different thicknesses of aluminum. Thickness in millimeters (mm) is shown on the x-axis, and a relative conversion factor value is shown on the y-axis. For the first series of data points **512**, the thickness is equal to the thickness of a carbon fiber skin that surrounds a foam core of the tabletop **362**. For example, the foam core may have a thickness of 38 mm, and the foam core may be surrounded on either side (e.g., a first side in face-sharing contact with the aluminum filtration measurement tool **350** and a second side in face-sharing contact with the detector **206**) by a 1 mm carbon fiber skin, such that a thickness of the tabletop **362** is 2 mm. For the second series of data points **514**, the thickness is equal to a thickness of a respective aluminum step of the series of aluminum steps of the aluminum filtration scale **352**.

[0046] Air kinetic energy released per unit mass (KERMA) is a sum of initial kinetic energies of all charged particles liberated by uncharged ionizing radiation in a sample of matter, divided by the mass of the sample. Described another way, air KERMA provides a measure of radiation dose in air. Air KERMA values of the tabletop **362** and each step of the series of aluminum steps of the aluminum filtration scale **352** may be directly compared to deduce an equivalent aluminum filtration of the tabletop **362**, since a way that the measurement of radiation dose in air is detected may not be influenced by the material the radiation passes through prior to detection.

[0047] The conversion factors may be identified using simulations of X-ray photon paths through matter. For example, a Geant4 simulation may be performed using characteristics of the imaging system **200**, the tabletop **362**, and the aluminum filtration measurement tool **350** to simulate and compare filtration of photons by the tabletop **362** and by the aluminum filtration scale **352**. For each photon emitted by irradiating beams of the vertical X-ray tube **204**, a path of the photon through matter (e.g., the tabletop **362**, the aluminum filtration measurement tool **350**) is simulated to determine whether or not the photon reaches the detector **206**. Material characteristics of the tabletop **362** and the aluminum filtration measurement tool **350** in the simulation are as described herein: the tabletop **362** formed of 38 mm foam with 2 mm carbon fiber skin; aluminum steps of the aluminum filtration measurement tool **350** made of equidistant steps with thicknesses of 0.4, 0.5, 0.6, 0.7, 0.8, 0.85, 0.9, and 1.0 mm; and thickness of the first planar surface **310**, the second planar surface **312**, and the vertical wall **358** equal to 3 mm. A design of experiment of the simulation is run to assess respective effects of foam density and carbon fiber thickness on photon absorption/transmission. Variables of the simulation may include foam density and carbon thickness. Simulations run to generate the air KERMA profile of the tabletop **362** simulate a detector made of pure air, instead of a detector including a CsI scintillator, to remove influence of how CsI scintillator response may vary among materials from the resulting profile. A simulation profile of each of the tabletop **362** and the aluminum filtration measurement tool **350** may include a ratio of primary photons to scatter photons detected by the detector (e.g., the pure air detector or the detector including the CsI scintillator). By comparing primary photon and scatter photon ratios of the CsI profile for the tabletop **362** and the simulated air KERMA response for the tabletop **362**, conversion factors are identified that may be used to correct the CsI profile for the tabletop **362** to the simulated air KERMA response for the tabletop **362**. These identified conversion factors may be used to correct experimental measurements of the CsI profile for the tabletop **362** (e.g., the first plot **502** of the first graph **510**) to acquire the air KERMA response for the tabletop (e.g., the first profile of a third graph **530**).

[0048] The third graph **530** of the first series of graphs **500** shows a first plot **532** illustrating an air KERMA profile of the tabletop **362**, and a second plot **534** illustrating an air KERMA profile of the aluminum filtration scale **352**. The air KERMA profiles are generated by applying respective conversion factors (e.g., from the second graph **520**) to the CsI detection profile of the tabletop **362** and the CsI detection profile of the aluminum filtration scale **352** (e.g., from the first graph **510**). For example, the first plot **532** of the third graph **530** may be acquired by applying conversion factors from the first series of data points **512** of the second graph **520** to the first plot **502** of the first graph **510**. The second plot **534** of the third graph **530** may be acquired by applying respective conversion factors from the second series of data points **514** of the second graph **520** to the second plot **504** of the first graph **510** to compute the air KERMA of the aluminum filtration scale. An air KERMA value is plotted along the y-axis, and a pixel value (e.g., a position in the X-ray image) is plotted along the x-axis. Similar to the first plot **502** of the first graph **510**, the first plot **532** of the third graph **530** has a dome-like shape. Additionally, similar to the second plot **504** of the first graph **510**, the second plot **534** of the third graph **530** includes a series of stepwise increases in the air KERMA profile that correspond to each step of the series of aluminum steps, and a dome-like shape on either end of the series of the stepwise increases. The dome-like shape of each of the first plot **532** and the second plot **534** may be an effect of scattered radiation, which may be corrected using scatter correction as further described herein with respect to FIGS. **6-7**.

[0049] An appropriate conversion factor of the first series of data points **512** to apply to the CsI detection profile of the tabletop **362** (e.g., shown in the first plot **502** of the first graph **510**) may be unknown. Simulations may be performed to identify a conversion factor for the CsI detection profile of the tabletop **362**. For example, a desired aluminum filtration equivalence of the tabletop **362** may be equal to filtering provided by aluminum having a known thickness between 0.6 mm and 0.7 mm. The second graph **520** includes relative conversion factors for desired aluminum filtration in the second series of data points **512**, where application of a relative conversion factor to a corresponding aluminum thickness value provides a corrected aluminum filtration value for the given aluminum thickness, as shown in the third graph **530**, compared to the first graph **510**. As described above, appropriate conversion factors that may be applied to the first plot **502** of the first graph **510** to achieve a similarly corrected tabletop filtration (e.g., compared to correction of the desired aluminum filtration) may be unknown. A conversion factor may be chosen from the first series of data points **512**, shown in the second graph **520**, that provides a systematic overestimation of the aluminum equivalence. For example, a conversion factor value of the first series of data points **512** that is between the thickness of 0.6 mm and 0.7 mm may be selected, as the conversion factor for the second series of data points **514** between the thickness of 0.6 mm and 0.7 mm provides desired correction of the aluminum filtration. As shown in the third graph **530** of FIG. **5**, the first plot **532** and the second plot **534** intersect at an aluminum step thickness between 0.6 mm and 0.7 mm. The selected conversion factors for the first series of data points **512** and the second series of data points **514** therefore correct the first plot **502** and the second plot **504** to provide the first plot **532** and the second plot **534**, respectively, as shown in the third graph **530**.

[0050] Turning to FIG. **6**, a graph **600** is shown of a scatter photon to primary photon ratio of the tabletop **362** that may be used in scatter correction of the CsI detection profile of the tabletop **362**. The graph **600** includes scatter to primary photon ratios for different tabletop thicknesses. Data are obtained from global average values of the tabletop window **354**. Most of the scattered variability is the result of a thickness of the carbon fiber skin, and foam density has less of an impact on scattered variability. The scatter photon to primary photon ratio of the tabletop as shown in the graph **600** may be used to correct the scatter of the CsI aluminum equivalence of the tabletop, as further described herein.

[0051] A first plot **602** of the graph **600** illustrates a scatter to primary photon ratio of the tabletop with a carbon skin thickness of 1.5 mm. A second plot **604** of the graph **600** illustrates a scatter to primary photon ratio of the tabletop with a carbon skin thickness of 1.95 mm. The scatter to primary ratio is shown along the y-axis as a percentage, and an apparent equivalent aluminum filtration of the tabletop, from CsI detector data, is shown along the x-axis in millimeters. Each of the first plot **602** and the second plot **604** increase linearly, where the scatter to primary photon ratio increases as the apparent equivalent aluminum filtration thickness increases.

[0052] In reality, primary and scatter signals of the tabletop **362** are unknown. Scatter of the tabletop may be estimated from the apparent equivalent aluminum filtration of the total brightness signal of the tabletop. For example, the apparent equivalent aluminum filtration is obtained by interpolation of the primary aluminum CsI signal to a total tabletop signal. The scatter to primary photon ratio (SPR) of the tabletop, provided by the simulation, may be used as a function of the apparent equivalent aluminum filtration. A primary signal under the tabletop may then be computed. For example, the SPR of the tabletop is shown as a dashed line **606** in the graph **600**. The dashed line **606** intersects the first plot **602** and the second plot **604** at the primary signal for the respective tabletop thickness, as indicated by an arrow **608**. A true scatter fraction of the tabletop may be obtained from the apparent equivalent aluminum filtration thickness in this way by deducing the scatter fraction from the total signal.

[0053] Turning to FIG. **7**, a graph **700** shows an effect of a scatter point spread function (ScPSF) of corresponding aluminum step thicknesses. A shape of a scatter signal is deduced from integration of the ScPSF over the irradiated area. As described with respect to FIG. **5**, CsI detector profiles of the tabletop **362** and of the aluminum filtration scale **352** have dome-like shapes due to influence of scatter photons. An aluminum step thickness in millimeters is shown along the x-axis, and a fraction of total scatter signal in each tabletop region of interest is shown along the y-axis. The graph **700** includes multiple plots **710**, each of which illustrates a run of the simulation where each run has a different foam thickness and/or carbon fiber skin thickness, as shown in the table **702**. The distribution of total scattered signal in each tabletop region of interest (e.g., corresponding to an aluminum step of the series of aluminum steps) is deduced from a convolution operation that provides a scattered signal shape over an irradiated area (e.g., the tabletop **362** exposed via the tabletop window **354**). As described with respect to FIGS. **10**A-**10**B, the ScPCF and the SPR of the tabletop may be used in scatter correction of the CsI detector profile of the tabletop (e.g., shown in FIG. **5**).

[0054] FIG. **8** shows a graph **800** illustrating a CsI detector profile to air KERMA conversion factor ratio as determined using simulations and measurements. The graph **800** may be used to identify an appropriate conversion factor to be used to convert the CsI detector profile of the tabletop to the air KERMA of the tabletop. An aluminum thickness or equivalent aluminum thickness in millimeters is shown on the x-axis. The y-axis shows a relative conversion factor, and a corresponding brightness (e.g., of the aluminum scale and/or the tabletop). A first plot **802** shows simulated values of a carbon (e.g., of the carbon fiber skin of the tabletop) X-ray beam quality. A second plot **804** shows simulated aluminum (e.g., of the aluminum filtration scale) X-ray beam quality. A third plot **806** shows a measured conversion factor of the tabletop, and a fourth plot **808** shows a measured conversion factor of the aluminum scale. As described above, the conversion factors may be generated from simulations comparing CsI detector profiles of each of the tabletop and the aluminum scale to respective air KERMA values, and deducing the conversion factor.

[0055] FIG. **9** shows a graph **900** illustrating a first plot **902** of aluminum scale air KERMA, and a second plot **904** of tabletop air KERMA. The first plot **902** and the second plot **904** are illustrated as ratios of air KERMA to aluminum thickness, and an intersection of the first plot **902** and the second plot **904** at approximately 0.8 mm Al provides the air equivalent aluminum filtration of the tabletop.

[0056] The method for measuring the air equivalent aluminum filtration of the tabletop is now described with respect to FIGS. **10**A-**10**B and with reference to FIGS. **1-9**. Briefly, the method comprises acquiring a single X-ray image of a tabletop and an aluminum filtration scale captured using an X-ray detector (e.g., a CsI scintillator detector), identifying a brightness of the tabletop and a brightness of the aluminum filtration scale in the single X-ray image, computing an aluminum equivalence of the tabletop, converting the brightness of the aluminum filtration scale to an air KERMA of the aluminum filtration scale and converting the aluminum equivalence of the tabletop to an air KERMA of the tabletop, and comparing the air KERMA of the tabletop to the air KERMA of the aluminum filtration scale to identify an air equivalent aluminum filtration of the tabletop. Further details of the method are provided in the description of FIGS. **10**A-**10**B. The method is described with respect to FIGS. **10**A-**10**B in the context of an X-ray detector configured as a CsI scintillator detector, thus equivalence of the tabletop may be referred to as CsI equivalence of the tabletop. In other examples where other types of X-ray detectors may be used, the equivalence of the tabletop may be determined using the method described herein, and using different coefficients of calculation (e.g., conversion factors) that are relative to the X-ray detector type, and which may be determined using methods similar to those described herein.

[0057] FIGS. **10**A-**10**B show a flow chart of a method **1000** for measuring an equivalent aluminum filtration of a tabletop using an X-ray imaging system. The X-ray imaging system that stores and executes the method **1000** may be configured as a manufacturing and quality control X-ray imaging system. Described another way, the X-ray system that executes the method **1000** may not be a medical X-ray imaging system configured to capture X-ray images of patients or other imaging subjects for image analysis purposes. The X-ray imaging system may be similar to, or the same as, the X-ray imaging system **200** of FIG. **2**. As described herein, the method **1000** is used to measure an equivalent aluminum filtration of a tabletop, or a section of the tabletop. The tabletop may be an example of a tabletop that is used in medical X-ray imaging systems to position a patient or other imaging subject, such as the support surface **138** of the medical imaging system **100** of FIG. **1**. Instructions for carrying out the method **1000** may be executed by a controller (e.g., electronic controller **216** described above with reference to FIG. **2**) based on instructions stored on a memory of the controller and in conjunction with signals received from sensors of the imaging system, such as the detector **206** described above with reference to FIG. **2**.

[0058] Beginning at FIG. **10**A, at **1002**, the method **1000** includes acquiring a single X-ray image of the tabletop and the aluminum filtration scale. For example, the single X-ray image (herein, “the X-ray image”) includes visualizations of both the tabletop and the aluminum filtration scale. As described with respect to FIGS. **3**A-**4**, the tabletop is positioned on the detector, and the aluminum filtration measurement tool is positioned in part on the tabletop and in part on the detector, such that a portion of the tabletop is exposed to air through the tabletop window, and the aluminum filtration scale is positioned on the detector. For example, the first planar surface of the aluminum filtration measurement tool is in face-sharing contact with the tabletop, and the second planar surface is in face-sharing contact with the detector of the X-ray imaging system. Capturing the X-ray image includes, at **1004**, simultaneously exposing the tabletop and the aluminum filtration scale to X-ray beams. The aluminum filtration tool acts to shield the tabletop, except for a portion of the tabletop exposed via the tabletop window, from the X-ray beams. X-ray beams pass through the exposed portion of the tabletop and into the CsI scintillator and the detector of the X-ray imaging system, as described with respect to FIGS. **1-2**. Further, X-ray beams pass through and are filtered by the aluminum filtration scale of the aluminum filtration tool, and into the detector of the X-ray imaging system. Thus, the X-ray image of the tabletop and the aluminum filtration scale is captured. For example, the X-ray image may be the X-ray image **400** shown and described with respect to FIG. **4**. As described herein, characteristics of the irradiating beams, such as a beam strength, may be changed by material properties of the tabletop.

[0059] At **1006**, the method **1000** includes identifying a location of the tabletop window and a location of the aluminum filtration scale in the X-ray image captured at **1002**. The location of the tabletop window and the location of the aluminum filtration scale may be automatically identified by applying a filter, such as a Canny filter or other edge detection filter, to the X-ray image. The filter may locate and identify the tabletop window and the aluminum filtration scale, and may provide a filtered image, an annotated X-ray image, and/or pixel coordinate locations in the image identifying each location.

[0060] At **1008**, the method **1000** includes splitting the aluminum filtration scale image (e.g., the portion of the X-ray image identified as the location of the aluminum filtration scale) into aluminum steps. As described with respect to FIGS. **3**A-**4**, the aluminum filtration scale comprises multiple aluminum steps having different aluminum thicknesses. The different aluminum thicknesses of the multiple aluminum steps may filter the X-ray beams by different amounts, and thus a brightness of each aluminum step captured in the X-ray image may be different. Splitting the aluminum filtration scale image into the multiple aluminum steps may include, at **1010**, applying a Sobel filter to the X-ray image. The Sobel filter may be applied horizontally to the X-ray image (e.g., such that Sobel projection lines are parallel with the center line **314** of the aluminum filtration measurement tool **350** of FIGS. **3**A-**4**). Splitting the aluminum filtration scale image may further include, at **1012**, identifying peaks at relevant locations in the aluminum filtration scale image using the Sobel filter, and identifying tolerance of peak locations to acquire non-adjacent step locations. For example, peaks may be identified between each aluminum step, and may be used to deduce borders (e.g., a left edge and a right edge) of each aluminum step, where the borders are parallel to the center line **314** of the aluminum filtration measurement tool **350**.

[0061] At **1014**, the method **1000** includes computing an average brightness of each aluminum step from the X-ray image, excluding signals greater than 2.5 sigma from the average brightness. The average brightness of each aluminum step may represent a strength of the X-ray beams after being filtered by the respective aluminum step thickness. The average brightness of an aluminum step may be, for example, an average row signal provided by the detector. Calculating the average brightness of each aluminum step may include: calculating an initial average brightness using all brightness values of the given aluminum step, identifying brightness values greater than 2.5 sigma from the initial average brightness, and recalculating the average brightness of the aluminum step by excluding the brightness values identified as being greater than 2.5 sigma from the recalculated average brightness. An example flow chart of a method for calculating average brightness of a step, excluding brightness values greater than 2.5 sigma from the initial average brightness, is described with respect to calculating average tabletop brightness in FIG. **11**, and may be similarly applied to calculating average brightness of each aluminum step.

[0062] At **1016**, the method **1000** includes subtracting a scatter fraction from the average brightness of each aluminum step. As described with respect to FIGS. **5-7**, photons of the X-ray beam may be scattered during filtration and transmission through each aluminum step of the series of aluminum steps. The scatter fraction of each aluminum step may be identified using simulations, such as

Geant4 simulations. The scatter fraction may be subtracted from the average brightness of the respective aluminum step to acquire a primary photon measurement of each aluminum step.

[0063] At **1018**, the method **1000** includes computing an average brightness of the tabletop window excluding signals greater than 2.5 sigma from the average brightness. The average brightness of the tabletop window may represent a strength of the X-ray beams after being filtered by the tabletop (e.g., the carbon fiber skin and the foam). The average brightness of the tabletop window may be, for example, an average signal provided by the detector. As described with respect to operation **1014** and further described with respect to operation **1024** and FIG. **11**, calculating the average brightness of the tabletop may include identifying and excluding signals greater than 2.5 sigma from the average brightness to assist in reducing scatter effects and thus increasing accuracy of equivalence determination.

[0064] At **1020**, the method **1000** includes computing an equivalence of the tabletop from the X-ray image. As briefly described above, the detector of the X-ray imaging system may include a CsI scintillator that converts received X-ray beams to visible light. Computing a CsI equivalence of the tabletop may include, at **1022**, identifying steps of the tabletop window. Neither the tabletop window nor the tabletop itself may be physically divided into steps, the image of the tabletop in the X-ray image may be divided into steps to assist in data organization and processing. For example, a size (e.g., a height) of adjacent aluminum steps may be translated to the tabletop to divide the tabletop into the same number of steps as the aluminum filtration scale. Computing the CsI equivalence of the tabletop may further include, at **1024**, calculating an average brightness excluding tabletop brightness signals distant by more than 2.5 sigma of the average brightness value. Further details regarding exclusion of tabletop brightness signals distant by more than 2.5 sigma of the average brightness value are described with respect to FIG. **11**.

[0065] Turning briefly to FIG. **11**, a method **1100** is shown for performing an iterative cleanup of individual pixels of the tabletop window in the X-ray image. For example, an average tabletop step brightness may be computed for each tabletop step identified at **1022**. As briefly described with respect to FIGS. **5-7**, scatter photons from the X-ray beam may cause unequal distribution, where a brightness is weaker around a perimeter of the tabletop window. Brightness of the tabletop at a single tabletop step may not be representative of total filtration by the tabletop. Therefore, brightness values distant by more than 2.5 sigma of the average value are removed from a total tabletop brightness calculation. Removed brightness values are not retained for average computations, as described herein with respect to the method **1000**. A threshold distance above which brightness signals are removed may be configurable. In the example described herein, the threshold distance is 2.5 sigma from the average brightness value. In other examples, the threshold distance may be greater than or less than 2.5 sigma from the average brightness value.

[0066] At **1102**, the method **1100** includes identifying a first region of interest (i) in the tabletop window. As described with respect to operation **1022** of the method **1000**, the first region of interest may be a step of the tabletop window. For example, the step of the tabletop window may be a section of the tabletop window within the first region **428**, as described with respect to FIGS. **4-5**.

[0067] At **1104**, the method **1100** includes calculating an average brightness of the first region of interest. As described herein, photons of the X-ray beam may be scattered during filtration and transmission through the tabletop. The average brightness of the tabletop window may be, for example, an average of signals provided by the detector.

[0068] At **1106**, the method **1100** includes calculating a standard deviation of the region of interest. Calculating the standard deviation may include calculating the standard deviation of brightness values used to calculate the average brightness at operation **1104**.

[0069] At **1108**, the method **1100** includes performing a count of pixels to identify a brightness values that are distant by more than 2.5 sigma of the average value (e.g., the average brightness of the first region of interest, calculated at operation **1104**). Performing the count of pixels includes calculating an absolute value of a difference of individual pixel (p) values for each pixel (e.g., p(n), p(n+1), etc.) and the average value (M(i)), and identifying values that are greater than a product of 2.5 (e.g., sigma value) and the standard deviation value (S(i)). The count of pixels may be performed as shown in equation 1:

$$|p(n)-M(i)|>2.5*S(i) \quad (1).$$

[0070] At **1110**, the method **1100** includes determining if there are more than zero pixels in the region of interest that have a brightness value distant by more than 2.5 sigma of the average value. If there are greater than zero pixels in the region of interest (e.g., if one or more pixels in the region of interest) has a brightness value that distant by more than 2.5 sigma of the average value), the method proceeds to **1112**.

[0071] At **1112**, the method **1100** includes excluding pixels identified as having brightness values distant by more than 2.5 sigma of the average value from a total tabletop brightness calculation. This may include generating a brightness value dataset to be used in further calculations, as further described herein, where the brightness value dataset includes pixels having brightness values that are distant by less than 2.5 sigma of the average value.

[0072] Returning briefly to operation **1110**, if it is determined there are not greater than zero pixels in the region of interest with a brightness value distant by more than 2.5 sigma of the average value, the method **1100** proceeds to operation **1114**. At operation **1114**, the method **1100** includes calculating an average total tabletop brightness. As described with respect to operation **1112**, the average total tabletop brightness may be calculated from a dataset, such as the brightness value dataset, that includes pixels having brightness values that are distant by less than 2.5 sigma of the average value.

[0073] The method **1100** may be repeated for each region of interest of the tabletop window. In this way, a dataset of pixels and respective brightness thereof that are used to calculate the average total tabletop brightness may be iteratively “cleaned”, such that some pixels may be excluded from the dataset and not retained for average computations, based on a relative brightness value.

[0074] The method **1000** continues in FIG. **10**B. At **1026**, the method **1000** includes deducing a global scatter fraction of the tabletop using the equivalence of the tabletop (e.g., computed at **1020**). As described with respect to FIGS. **5-7**, a total scatter to primary photon ratio may be unknown for the tabletop, and a global scatter fraction may be estimated using simulations.

[0075] At **1028**, the method **1000** includes computing a scatter profile of the tabletop from the scatter fraction of the tabletop. Computing the scatter profile of the tabletop includes, at **1030**, deducing a fraction of the scatter profile at each tabletop step. At **1032**, the method **1000** includes subtracting the scatter fraction of each tabletop step from the respective tabletop step brightness.

[0076] At **1034**, the method **1000** includes converting the brightness of each aluminum step and the brightness of each tabletop step to air KERMA values using respective conversion factors. As described herein with respect to FIGS. **5-9**, the conversion factor may be identified using simulations and comparisons of aluminum filtration (e.g., from the aluminum filtration scale) in air (e.g., air KERMA of the aluminum filtration scale) and as detected by the CsI scintillator (e.g., CsI aluminum equivalence of the tabletop).

[0077] At **1036**, the method **1000** includes computing an air equivalent aluminum filtration value of the tabletop by finding an intersection of the tabletop filtration and the aluminum step filtration, using the air KERMA values. As described with respect to FIG. **9**, the air equivalent aluminum filtration value of the tabletop provides a relative filtering provided by the tabletop in terms of aluminum filtering.

[0078] At **1038**, the method **1000** includes determining whether the air equivalent aluminum filtration of the tabletop is less than a threshold filtration value. The threshold filtration value may be, for example, 0.80 mm Al. When the air equivalent aluminum filtration of the tabletop is less than the threshold filtration value, the tabletop may provide at least a desired amount of filtering. When the air equivalent aluminum filtration of the tabletop is equal to or greater than the threshold filtration value, the tabletop may provide more than a desired amount of filtering. If the air equivalent aluminum filtration value of the tabletop is less than the threshold filtration value, the method **1000** proceeds to **1040**.

[0079] At **1040**, the method **1000** include outputting a “pass” indicator and two flanking aluminum step thicknesses for display, as well as storing results of the method **1000**. For example, the “pass” indicator may be a text-based message, a graphic, a color indicator, and so on. The results of the method **1000** that are stored may include values used to calculate the air equivalent aluminum filtration value of the tabletop, including locations of the aluminum steps of the aluminum filtration scale, locations of regions of interest of the tabletop, CsI detector profiles for the aluminum filtration scale and the tabletop, scatter factors and other scatter ratios, and air KERMA values of the tabletop and the aluminum filtration scale.

[0080] If the air equivalent aluminum filtration value of the tabletop is not less than the threshold filtration value at **1038**, the method **1000** proceeds to **1042**. At **1042**, the method **1000** includes outputting a “fail” indicator and two flanking aluminum step thicknesses for display, as well as storing results of the method **1000**. For example, the “fail” indicator may be a text-based message, a graphic, a color indicator, and so on.

[0081] After either **1040** or **1042**, method **1000** may end.

[0082] In this way, the method and systems described herein address expected impending obsolescence of current radiographic methods and continuously increasing cost of radiographic material (film, development chemical products). In addition, the methods and systems described herein will decrease resource demand, since it provides a final performance from a single digital X-ray image instead of human readout of a developed radiographic film. The systems and methods described herein provides the tabletop value faster than may be acquired using radiographic film development, and has the potential to reduce errors from human interpretation of radiographic film by a repeatable software analysis of a digital image.

[0083] The disclosure also provides support for a method for an X-ray system, comprising: acquiring a single X-ray image of a tabletop and an aluminum filtration scale using a detector, identifying a brightness of the tabletop and a brightness of the aluminum filtration scale in the single X-ray image, computing an aluminum equivalence of the tabletop, converting the brightness of the aluminum filtration scale to an air kinetic energy released per unit mass (KERMA) of the aluminum filtration scale and converting the aluminum equivalence of the tabletop to an air KERMA of the tabletop, and comparing the air KERMA of the tabletop to the air KERMA of the aluminum filtration scale to identify an air equivalent aluminum filtration of the tabletop. In a first example of the method, the single X-ray image is acquired using a cesium iodide (CsI) scintillator detector. In a second example of the method, optionally including the first example, the method further comprises: deducing a global scatter of the tabletop, and subtracting the global scatter of the tabletop from the aluminum equivalence of the tabletop. In a third example of the method, optionally including one or both of the first and second examples, converting the brightness of the aluminum filtration scale to the air KERMA of the aluminum filtration scale comprises applying a first conversion factor to the brightness of the aluminum filtration scale, and converting the aluminum equivalence of the tabletop the air KERMA of the aluminum equivalence comprises applying a second conversion factor, different from the first conversion factor, to the aluminum equivalence of the tabletop. In a fourth example of the method, optionally including one or more or each of the first through third examples, the aluminum filtration scale comprises a series of aluminum steps that each have a different aluminum thickness, and identifying the brightness of the aluminum filtration scale comprises identifying an average brightness of each aluminum step of the series of aluminum steps. In a fifth example of the method, optionally including one or more or each of the first through fourth examples, the method further comprises: deducing a step scatter of each step of the series of aluminum steps, and subtracting a respective step scatter from the average brightness of each aluminum step. In a sixth example of the method, optionally including one or more or each of the first through fifth examples, converting the brightness of the aluminum filtration scale to the air KERMA of the aluminum filtration scale comprises converting the average brightness of each aluminum step to an air KERMA of each aluminum step. In a seventh example of the method, optionally including one or more or each of the first through sixth examples, identifying the air equivalent aluminum filtration of the tabletop comprises comparing the air KERMA of the tabletop to the air KERMA of each aluminum step, and identifying a thickness of an aluminum step of the series of aluminum steps having an air KERMA value that is equal to the air KERMA of the tabletop. In an eighth example of the method, optionally including one or more or each of the first through seventh examples, the method further comprises, determining if the air equivalent aluminum filtration of the tabletop is less than a threshold filtration and, in response to the air equivalent aluminum filtration of the tabletop being less than the threshold filtration, outputting a “pass” indicator, values of two flanking aluminum step thicknesses, and storing results of the method in memory.

[0084] The disclosure also provides support for an X-ray imaging system, comprising: an X-ray tube, a detector, an aluminum filtration measurement tool having a tabletop window and an aluminum filtration scale, and a controller with computer-readable instructions stored on non-transitory memory that, when executed, cause the controller to: acquire a single X-ray image in a single scan of a tabletop, positioned on the detector, and the aluminum filtration measurement tool, where the aluminum filtration measurement tool is positioned in part on the tabletop and in part on the detector, such that a portion of the tabletop is exposed to air through the tabletop window, and the aluminum filtration scale is positioned on the detector, identify, in the single X-ray image, a brightness of the portion of the tabletop exposed to air and a brightness of the aluminum filtration scale, compute an aluminum equivalence of the portion of the tabletop exposed to air, scatter correct the aluminum equivalence of the portion of the tabletop exposed to air and the brightness of the aluminum filtration scale, convert a scatter-corrected aluminum equivalence of the portion of the tabletop exposed to air and a scatter-corrected brightness of the aluminum filtration scale to an air KERMA of the tabletop and an air KERMA of the aluminum filtration scale, respectively, and compare the air KERMA of the tabletop and the air KERMA of the aluminum filtration scale to identify an air equivalent aluminum filtration of the tabletop. In a first example of the system, the X-ray tube directs X-ray beams orthogonal to the tabletop and the aluminum filtration scale. In a second example of the system, optionally including the first example, the tabletop and the aluminum filtration scale are irradiated by X-ray beams from the X-ray tube that provide a half-value layer of greater than 3.6 aluminum equivalence for 100 kilovolts peak X-ray beam. In a third example of the system, optionally including one or both of the first and second examples, the aluminum filtration scale comprises a series of aluminum steps arranged in parallel along a length of the aluminum filtration scale, and each step of the series of aluminum steps has a different aluminum thickness from other steps of the series of aluminum steps. In a fourth example of the system, optionally including one or more or each of the first through third examples, the aluminum filtration measurement tool comprises: a first planar surface having the tabletop window extending through a thickness of the first planar surface, a second planar surface having an aluminum scale window extending through a thickness of the second planar surface, the second planar surface offset from and coupled to the first planar surface by a vertical wall, the vertical wall perpendicular to the first planar surface to the second planar surface, and the aluminum filtration scale positioned in the aluminum scale window. In a fifth example of the system, optionally including one or more or each of the first through fourth examples, the first planar surface is elevated above the second planar surface by a height of the vertical wall. In a sixth example of the system, optionally including one or more or each of the first through fifth examples, the aluminum filtration measurement tool is formed of lead and carbon.

[0085] The disclosure also provides support for a method for an X-ray imaging system, comprising: simultaneously irradiating a tabletop and an aluminum filtration scale having a series

of aluminum steps with different thicknesses using an X-ray beam, capturing photons filtered by tabletop and the aluminum filtration scale using a cesium iodide (CsI) scintillator detector, generating an X-ray image from captured photons, identifying a brightness of the tabletop and each step of the series of steps of the aluminum filtration scale in the X-ray image, computing a CsI aluminum equivalence of the tabletop, computing global scatter for the tabletop, subtracting scatter from the brightness of the tabletop and from each step of the series of steps of the aluminum filtration scale to generate a scatter-free brightness value of the tabletop and a scatter-free brightness value of each step of the aluminum filtration scale, converting the scatter-free brightness value of the tabletop and the scatter-free brightness value of each step of the aluminum filtration scale to a tabletop air KERMA value and a series of aluminum step air KERMA values, respectively, by applying a conversion factor to each, comparing the tabletop air KERMA value to the series of aluminum step air KERMA values to identify an air equivalent aluminum filtration of the tabletop, and storing the air equivalent aluminum filtration of the tabletop in memory and outputting the air equivalent aluminum filtration of the tabletop for display on a display device. In a first example of the method, identifying the brightness of the tabletop comprises: locating the tabletop, and defining individual regions of interest of the tabletop using the series of aluminum steps of the aluminum filtration scale, wherein each region of interest of the tabletop is parallel to an aluminum step of the series of aluminum steps. In a second example of the method, optionally including the first example, computing the CsI aluminum equivalence of the tabletop comprises comparing a brightness of each region of interest of the tabletop to the brightness of each step of the series of aluminum steps. In a third example of the method, optionally including one or both of the first and second examples, a first conversion factor is applied to the scatter-free brightness value of the tabletop and a second conversion factor, different from the first conversion factor, is applied to the scatter-free brightness value of each step of the aluminum filtration scale.
[0086] As used herein, the term “approximately” is construed to mean plus or minus five percent of the range unless otherwise specified.
[0087] As used herein, an element or step recited in the singular and preceded with the word “a” or “an” should be understood as not excluding plural of said elements or steps, unless such exclusion is explicitly stated. Furthermore, references to “one embodiment” of the present invention are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features. Moreover, unless explicitly stated to the contrary, embodiments “comprising,” “including,” or “having” an element or a plurality of elements having a particular property may include additional such elements not having that property. The terms “including” and “in which” are used as the plain-language equivalents of the respective terms “comprising” and “wherein.” Moreover, the terms “first,” “second,” and “third,” etc. are used merely as labels, and are not intended to impose numerical requirements or a particular positional order on their objects.
[0088] This written description uses examples to disclose the invention, including the best mode, and also to enable a person of ordinary skill in the relevant art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those of ordinary skill in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

Claims

1. A method for an X-ray system, comprising: acquiring a single X-ray image of a tabletop and an aluminum filtration scale using a detector; identifying a brightness of the tabletop and a brightness of the aluminum filtration scale in the single X-ray image; computing an aluminum equivalence of the tabletop; converting the brightness of the aluminum filtration scale to an air kinetic energy released per unit mass (KERMA) of the aluminum filtration scale and converting the aluminum equivalence of the tabletop to an air KERMA of the tabletop; and comparing the air KERMA of the tabletop to the air KERMA of the aluminum filtration scale to identify an air equivalent aluminum filtration of the tabletop.

2. The method of claim 1, wherein the single X-ray image is acquired using a cesium iodide (CsI) scintillator detector.

3. The method of claim 1, further comprising deducing a global scatter of the tabletop, and subtracting the global scatter of the tabletop from the aluminum equivalence of the tabletop.

4. The method of claim 1, wherein converting the brightness of the aluminum filtration scale to the air KERMA of the aluminum filtration scale comprises applying a first conversion factor to the brightness of the aluminum filtration scale, and converting the aluminum equivalence of the tabletop the air KERMA of the aluminum equivalence comprises applying a second conversion factor, different from the first conversion factor, to the aluminum equivalence of the tabletop.

5. The method of claim 1, wherein the aluminum filtration scale comprises a series of aluminum steps that each have a different aluminum thickness, and identifying the brightness of the aluminum filtration scale comprises identifying an average brightness of each aluminum step of the series of aluminum steps.

6. The method of claim 5, further comprising deducing a step scatter of each step of the series of aluminum steps, and subtracting a respective step scatter from the average brightness of each aluminum step.

7. The method of claim 6, wherein converting the brightness of the aluminum filtration scale to the air KERMA of the aluminum filtration scale comprises converting the average brightness of each aluminum step to an air KERMA of each aluminum step.

8. The method of claim 7, wherein identifying the air equivalent aluminum filtration of the tabletop comprises comparing the air KERMA of the tabletop to the air KERMA of each aluminum step, and identifying a thickness of an aluminum step of the series of aluminum steps having an air KERMA value that is equal to the air KERMA of the tabletop.

9. The method of claim 1, further comprising, determining if the air equivalent aluminum filtration of the tabletop is less than a threshold filtration and, in response to the air equivalent aluminum filtration of the tabletop being less than the threshold filtration, outputting a “pass” indicator, values of two flanking aluminum step thicknesses, and storing results of the method in memory.

10. An X-ray imaging system, comprising: an X-ray tube; a detector; an aluminum filtration measurement tool having a tabletop window and an aluminum filtration scale; and a controller with computer-readable instructions stored on non-transitory memory that, when executed, cause the controller to: acquire a single X-ray image in a single scan of a tabletop, positioned on the detector, and the aluminum filtration measurement tool, where the aluminum filtration measurement tool is positioned in part on the tabletop and in part on the detector, such that a portion of the tabletop is exposed to air through the tabletop window, and the aluminum filtration scale is positioned on the detector; identify, in the single X-ray image, a brightness of the portion of the tabletop exposed to air and a brightness of the aluminum filtration scale; compute an aluminum equivalence of the portion of the tabletop exposed to air; scatter correct the aluminum equivalence of the portion of the tabletop exposed to air and the brightness of the aluminum filtration scale; convert a scatter-corrected aluminum equivalence of the portion of the tabletop exposed to air and a scatter-corrected brightness of the aluminum filtration scale to an air KERMA of the tabletop and an air KERMA of the aluminum filtration scale, respectively; and compare the air KERMA of the tabletop and the air KERMA of the aluminum filtration scale to identify an air equivalent aluminum filtration of the tabletop.

11. The X-ray imaging system of claim 10, wherein the X-ray tube directs X-ray beams orthogonal to the tabletop and the aluminum filtration scale.

12. The X-ray imaging system of claim 10, wherein the tabletop and the aluminum filtration scale are irradiated by X-ray beams from the X-ray tube that provide a half-value layer of greater than 3.6 aluminum equivalence for 100 kilovolts peak X-ray beam.
13. The X-ray imaging system of claim 10, wherein the aluminum filtration scale comprises a series of aluminum steps arranged in parallel along a length of the aluminum filtration scale, and each step of the series of aluminum steps has a different aluminum thickness from other steps of the series of aluminum steps.
14. The X-ray imaging system of claim 13, wherein the aluminum filtration measurement tool comprises: a first planar surface having the tabletop window extending through a thickness of the first planar surface; a second planar surface having an aluminum scale window extending through a thickness of the second planar surface, the second planar surface offset from and coupled to the first planar surface by a vertical wall, the vertical wall perpendicular to the first planar surface to the second planar surface; and the aluminum filtration scale positioned in the aluminum scale window.
15. The X-ray imaging system of claim 14, wherein the first planar surface is elevated above the second planar surface by a height of the vertical wall.
16. The X-ray imaging system of claim 10, wherein the aluminum filtration measurement tool is formed of lead and carbon.
17. A method for an X-ray imaging system, comprising: simultaneously irradiating a tabletop and an aluminum filtration scale having a series of aluminum steps with different thicknesses using an X-ray beam; capturing photons filtered by tabletop and the aluminum filtration scale using a cesium iodide (CsI) scintillator detector; generating an X-ray image from captured photons; identifying a brightness of the tabletop and each step of the series of steps of the aluminum filtration scale in the X-ray image; computing a CsI aluminum equivalence of the tabletop; computing global scatter for the tabletop; subtracting scatter from the brightness of the tabletop and from each step of the series of steps of the aluminum filtration scale to generate a scatter-free brightness value of the tabletop and a scatter-free brightness value of each step of the aluminum filtration scale; converting the scatter-free brightness value of the tabletop and the scatter-free brightness value of each step of the aluminum filtration scale to a tabletop air KERMA value and a series of aluminum step air KERMA values, respectively, by applying a conversion factor to each; comparing the tabletop air KERMA value to the series of aluminum step air KERMA values to identify an air equivalent aluminum filtration of the tabletop; and storing the air equivalent aluminum filtration of the tabletop in memory and outputting the air equivalent aluminum filtration of the tabletop for display on a display device.
18. The method of claim 17, wherein identifying the brightness of the tabletop comprises: locating the tabletop; and defining individual regions of interest of the tabletop using the series of aluminum steps of the aluminum filtration scale, wherein each region of interest of the tabletop is parallel to an aluminum step of the series of aluminum steps.
19. The method of claim 18, wherein computing the CsI aluminum equivalence of the tabletop comprises comparing a brightness of each region of interest of the tabletop to the brightness of each step of the series of aluminum steps.
20. The method of claim 17, wherein a first conversion factor is applied to the scatter-free brightness value of the tabletop and a second conversion factor, different from the first conversion factor, is applied to the scatter-free brightness value of each step of the aluminum filtration scale.