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Rogers et al.

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(54) **APPARATUS AND METHOD FOR IMPROVED TRANSIENT RESPONSE IN AN ELECTROMAGNETICALLY CONTROLLED X-RAY TUBE**

(75) Inventors: **Carey Shawn Rogers**, Brookfield, WI (US); **Mark Alan Frontera**, Ballston Lake, NY (US); **Ethan James Westcot**, Wauwatosa, WI (US); **Peter Andras Zavodszky**, Clifton Park, NY (US)

(73) Assignee: **General Electric Company**, Schenectady, NY (US)

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H01J 35/14 (2006.01)

(52) **U.S. Cl.** **378/138**; 378/121

(58) **Field of Classification Search** 378/4–20, 378/62, 119–144

See application file for complete search history.

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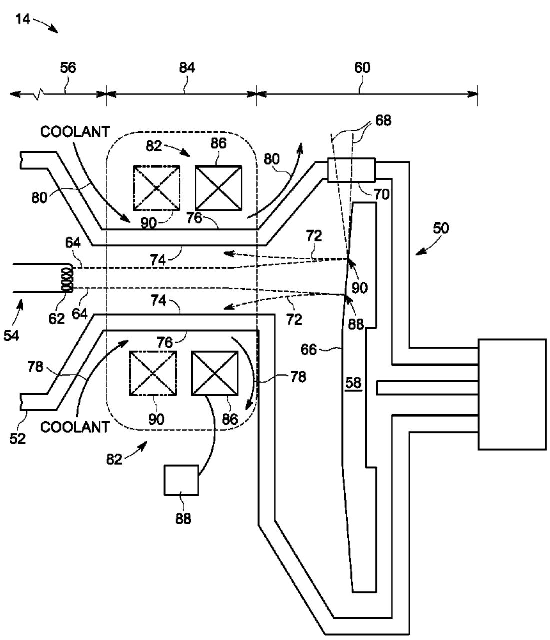
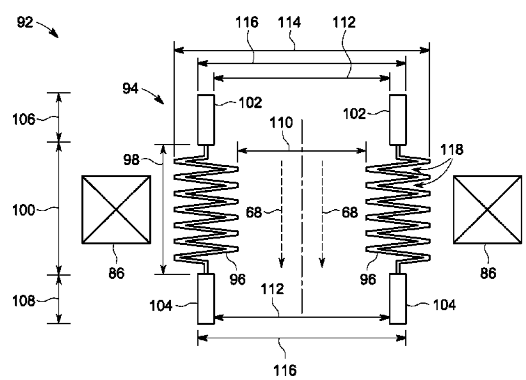
Primary Examiner — Courtney Thomas
(74) *Attorney, Agent, or Firm* — Ziolkowski Patent Solutions Group, SC

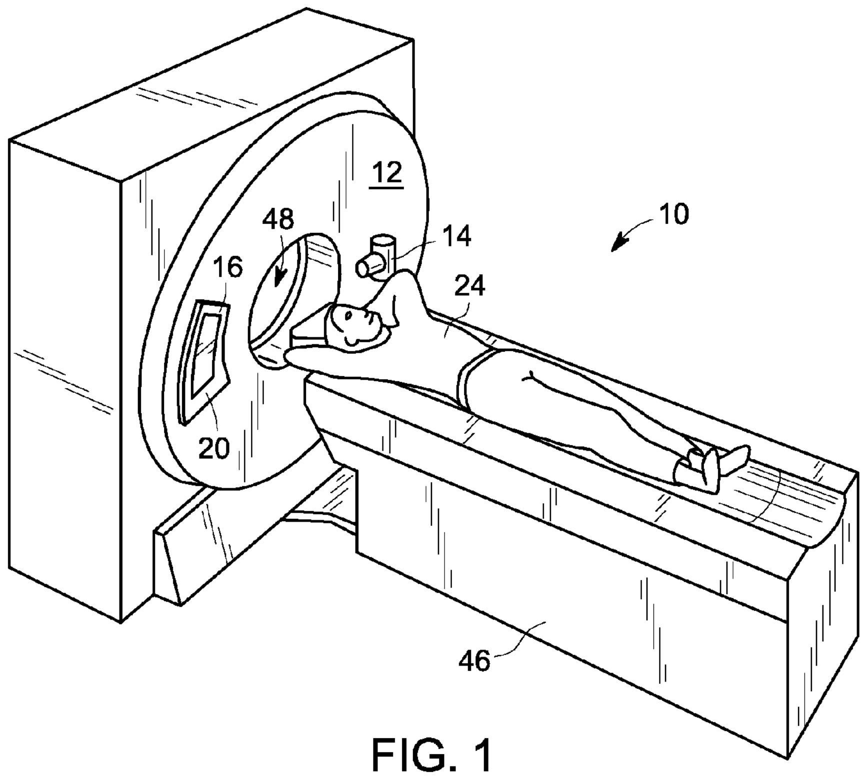
(57) **ABSTRACT**

An x-ray tube assembly includes a vacuum enclosure that has a cathode portion, a target portion, and a throat portion. The throat portion includes a metal bellows. An upstream end of the throat portion is coupled to the cathode portion and a downstream end of the throat portion is coupled to the target portion. The x-ray tube assembly also includes a target positioned within the target portion of the vacuum enclosure, and a cathode positioned within the cathode portion of the vacuum enclosure. The cathode is configured to emit a stream of electrons through the throat portion toward the target.

20 Claims, 5 Drawing Sheets



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46

FIG. 1

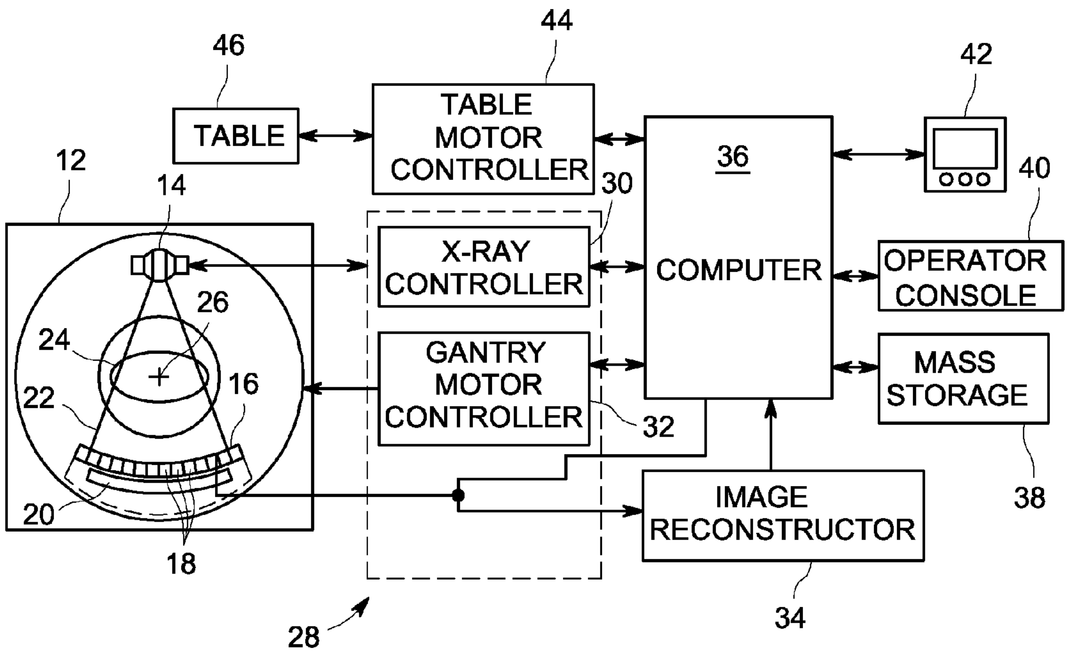
46
44
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TABLE
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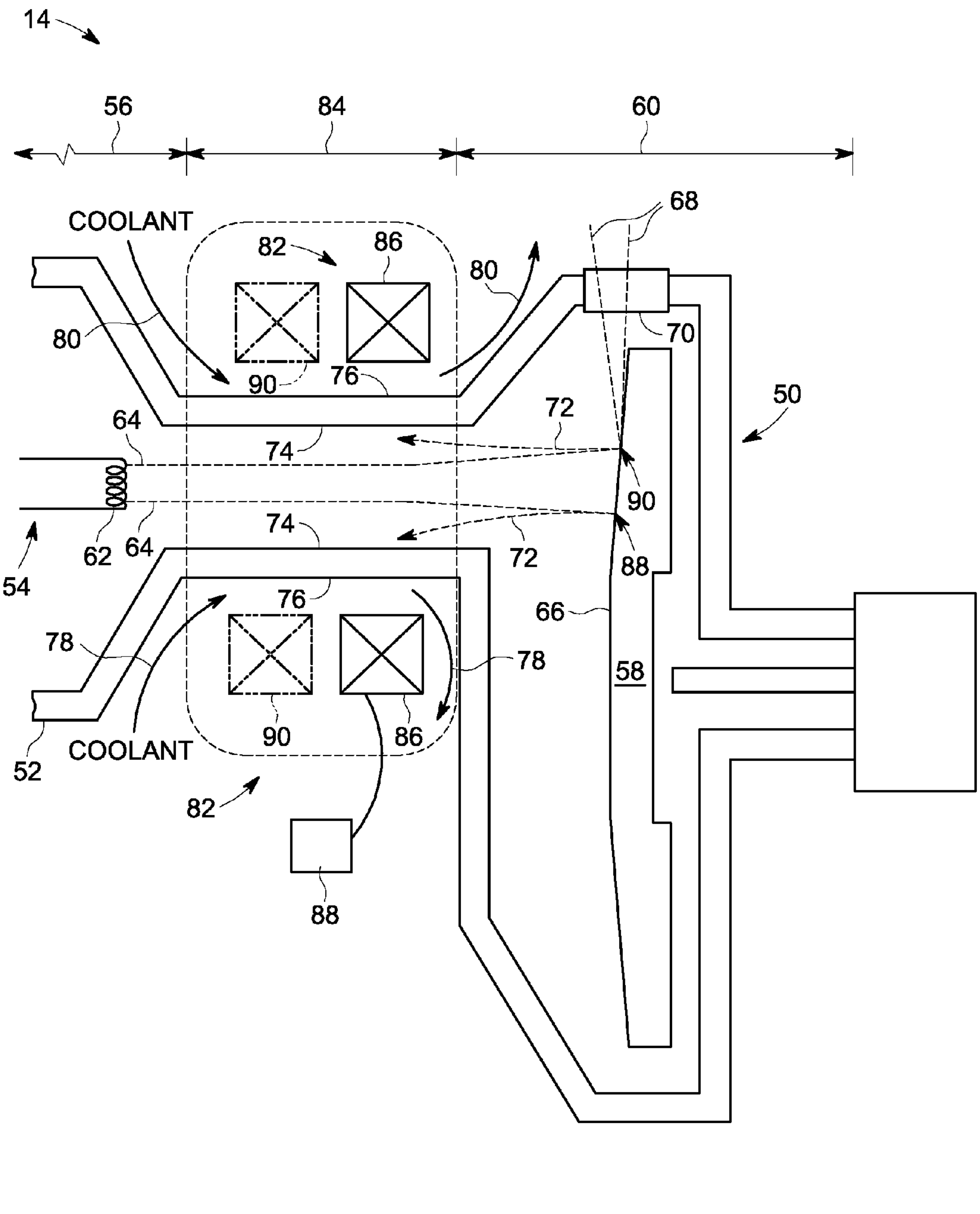
X-RAY CONTROLLER
COMPUTER
OPERATOR CONSOLE
26
24
GANTRY MOTOR CONTROLLER
MASS STORAGE
22
16
32
20
IMAGE RECONSTRUCTOR
38
18
28
34

FIG. 2


14
56
84
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COOLANT
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80
70
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50
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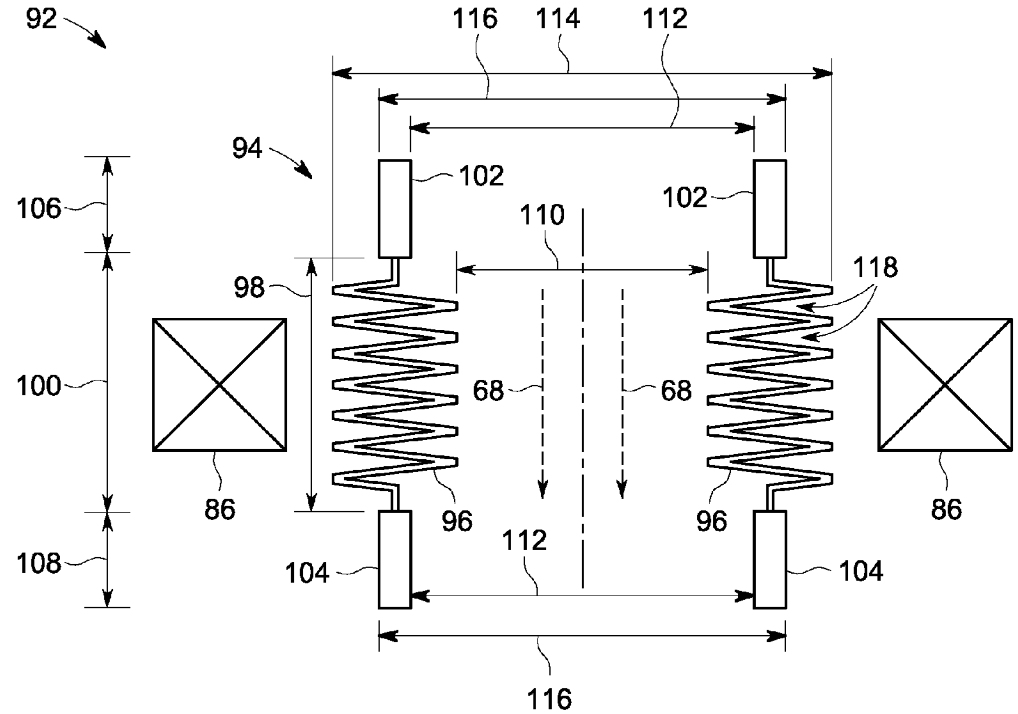
FIG. 3


92
116
114
112
94
102
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118
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98
100
68
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86
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104
104
116

FIG. 4

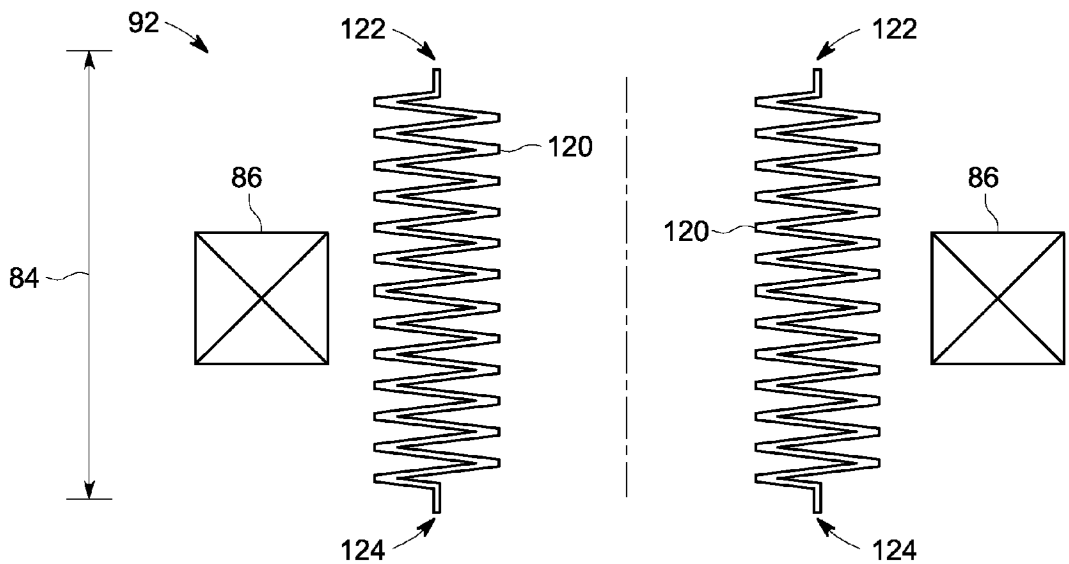
92
122
122
120
86
86
120
84
124
124

FIG. 5

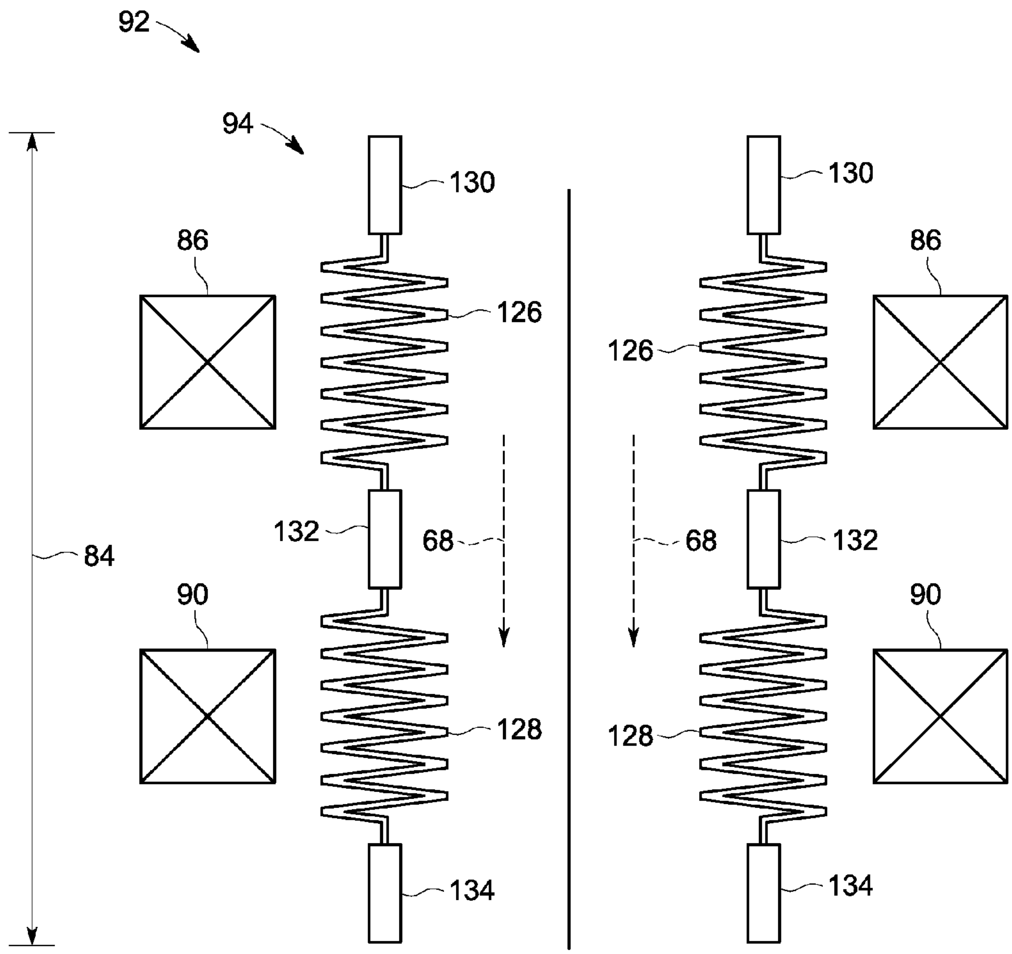

FIG. 6

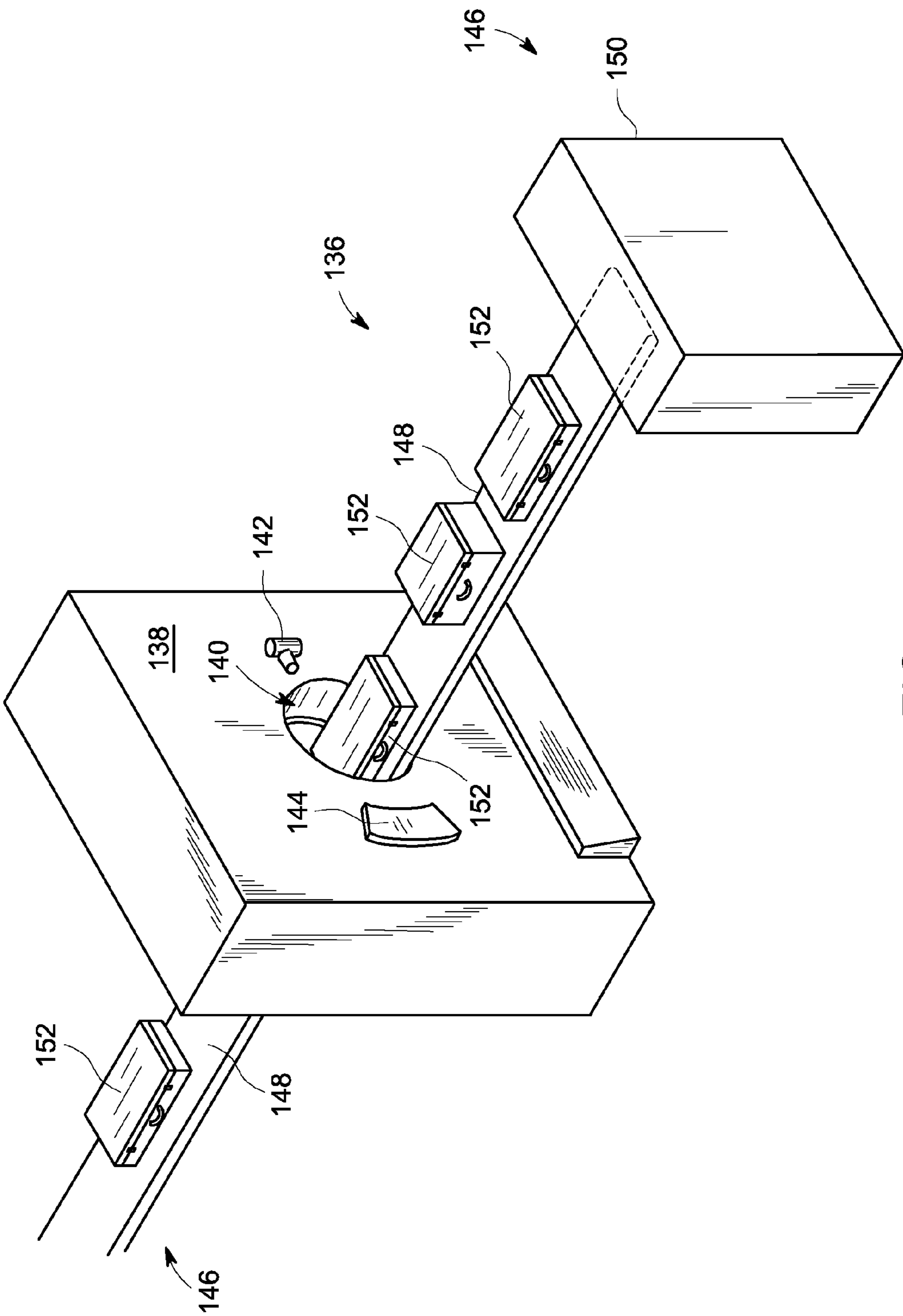

FIG. 7

APPARATUS AND METHOD FOR IMPROVED TRANSIENT RESPONSE IN AN ELECTROMAGNETICALLY CONTROLLED X-RAY TUBE

BACKGROUND OF THE INVENTION

Embodiments of the invention relate generally to diagnostic imaging and, more particularly, to an apparatus and method for improved transient response in an electromagnetically controlled x-ray tube.

X-ray systems typically include an x-ray tube, a detector, and a support structure for the x-ray tube and the detector. In operation, an imaging table, on which an object is positioned, is located between the x-ray tube and the detector. The x-ray tube typically emits radiation, such as x-rays, toward the object. The radiation typically passes through the object on the imaging table and impinges on the detector. As radiation passes through the object, internal structures of the object cause spatial variances in the radiation received at the detector. The detector then transmits data received, and the system translates the radiation variances into an image, which may be used to evaluate the internal structure of the object. One skilled in the art will recognize that the object may include, but is not limited to, a patient in a medical imaging procedure and an inanimate object as in, for instance, a package in an x-ray scanner or computed tomography (CT) package scanner.

X-ray tubes include a rotating target structure for the purpose of distributing the heat generated at a focal spot. The target is typically rotated by an induction motor having a cylindrical rotor built into a cantilevered axle that supports a disc-shaped target and an iron stator structure with copper windings that surrounds an elongated neck of the x-ray tube. The rotor of the rotating target assembly is driven by the stator.

One skilled in the art will recognize that the operation described herein need not be limited to a single X-ray tube configuration, but is applicable to any X-ray tube configuration. For instance, in one embodiment the target and frame of the X-ray tube may be held at ground potential and the cathode may be maintained at the desired potential difference, while in another embodiment the X-ray tube may operate in a bipolar arrangement having a negative voltage applied to a cathode and a positive voltage applied to an anode.

An x-ray tube cathode provides an electron beam that is accelerated using a high voltage applied across a cathode-to-target vacuum gap to produce x-rays upon impact with the target. The area where the electron beam impacts the target is often referred to as the focal spot. Typically, the cathode includes one or more cylindrical-coil or flat filaments positioned within a cup for providing electron beams to create a high-power, large focal spot or a high-resolution, small focal spot, as examples. Imaging applications may be designed that include selecting either a small or a large focal spot having a particular shape, depending on the application. Typically, an electrically resistive emitter or filament is positioned within a cathode cup, and an electrical current is passed therethrough, thus causing the emitter to increase in temperature and emit electrons when in a vacuum.

The shape of the emitter or filament and the shape of the cathode cup that the filament is positioned within affects the focal spot. In order to achieve a desired focal spot shape, the cathode may be designed taking the shape of the filament and cathode cup into consideration. However, the shape of the filament is not typically optimized for image quality or for thermal focal spot loading. Conventional filaments are primarily shaped as coiled or helical tungsten wires for reasons of manufacturing and reliability. Alternative design options may include alternate design profiles, such as a coiled D-shaped filament. Therefore, the range of design options for forming the electron beam from the emitter may be limited by the filament shape, when considering electrically resistive materials as the emitter source.

Electron beam (e-beam) wobbling is often used to enhance image quality. Wobble may be achieved using electrostatic e-beam deflection or magnetic deflection (i.e., spatial modulation), which utilizes a rapidly changing magnetic field to control the e-beam. Likewise, a rapidly changing magnetic field may be used to rapidly change the focusing of the electron beam (i.e., change the cross-sectional size of the electron beam in width and length directions). Typically, a pair of quadrupole magnets are used to achieve electron beam focusing in both width and length directions. For certain scan modes, such as rapid kV modulation, or so-called dual-energy scanning, the ability to rapidly adjust the focusing magnetic field is advantageous to maintain the focal spot size constant between the kV levels. Such electromagnetic e-beam control may achieve a high image quality by ensuring that the electron beam moves from one position to the next or refocuses as quickly as possible while staying in the desired position or at the desired focus without straying. However, when current in the electromagnets is rapidly changed to generate the changing magnetic field, eddy currents are generated in the vacuum vessel wall that opposes the magnetic field penetration inside the x-ray tube. The eddy currents increase the rise time of the magnetic field inside the throat of the x-ray tube, which slows the deflection or refocusing time of the e-beam. Accordingly, it would be desirable to design an x-ray tube having a throat portion that minimizes eddy current losses to optimize the transient magnetic field developed at the electron beam.

The configuration of the x-ray tube throat is subject to a number of design constraints. During operation, the throat experiences significant heat fluxes in the x-ray tube environment due to backscattered electrons from the target, for example. Further, the throat should be easy to manufacture and easy to join with interface components while still being capable of maintaining a hermetic vacuum and withstanding atmospheric pressure.

Therefore, it would be desirable to design an apparatus and method for improving the transient response in an electromagnetically controlled x-ray tube that satisfies the above-described design constraints and overcomes the aforementioned drawbacks.

BRIEF DESCRIPTION OF THE INVENTION

In accordance with one aspect of the invention, an x-ray tube assembly includes a vacuum enclosure that has a cathode portion, a target portion, and a throat portion. The throat portion includes a metal bellows. An upstream end of the throat portion is coupled to the cathode portion and a downstream end of the throat portion is coupled to the target portion. The x-ray tube assembly also includes a target positioned within the target portion of the vacuum enclosure, and a cathode positioned within the cathode portion of the vacuum enclosure. The cathode is configured to emit a stream of electrons through the throat portion toward the target.

In accordance with another aspect of the invention, an x-ray tube assembly includes a housing having a vacuum formed therein. The housing has a cathode portion, a target portion, and a throat portion that includes a bellows section. The x-ray tube assembly further includes a target positioned in the target portion of the vacuum housing, and a cathode positioned in the cathode portion of the vacuum housing to direct a stream of electrons toward the target.

In accordance with another aspect of the invention, In accordance with yet another embodiment, an imaging system includes a rotatable gantry having an opening therein for receiving an object to be scanned, a table positioned within the opening of the gantry and moveable through the opening, and an x-ray tube coupled to the gantry. The x-ray tube includes a vacuum chamber that has a target portion housing a target, a cathode portion housing a cathode, and a throat portion comprising a first bellows. The throat portion forms a passageway between the cathode portion and the target portion for a stream of electrons emitted from the cathode. The imaging system also includes a first electron manipulation coil mounted on the x-ray tube and aligned with the bellows. The first electron manipulation coil is configured to generate a first magnetic field within the throat portion to manipulate the stream of electrons therein.

Various other features and advantages will be made apparent from the following detailed description and the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings illustrate preferred embodiments presently contemplated for carrying out the invention.

In the drawings:

FIG. **1** is a pictorial view of an imaging system.

FIG. **2** is a block schematic diagram of the system illustrated in FIG. **1**.

FIG. **3** is a cross-sectional view of an x-ray tube assembly according to an embodiment of the invention and useable with the imaging system illustrated in FIG. **1**.

FIG. **4** is an enlarged portion of the throat of the x-ray tube assembly of FIG. **3**, according to an embodiment of the invention.

FIG. **5** is an enlarged portion of the throat of the x-ray tube assembly of FIG. **3**, according to another embodiment of the invention

FIG. **6** is an enlarged portion of the throat of the x-ray tube assembly of FIG. **3**, according to yet another embodiment of the invention

FIG. **7** is a pictorial view of an x-ray system for use with a non-invasive package inspection system according to an embodiment of the invention.

DETAILED DESCRIPTION

The operating environment of embodiments of the invention is described with respect to a computed tomography (CT) system. It will be appreciated by those skilled in the art that embodiments of the invention are equally applicable for use with any multi-slice configuration. Moreover, embodiments of the invention will be described with respect to the detection and conversion of x-rays. However, one skilled in the art will further appreciate that embodiments of the invention are equally applicable for the detection and conversion of other high frequency electromagnetic energy. Embodiments of the invention will be described with respect to a “third generation” CT scanner, but is equally applicable with other CT systems, surgical C-arm systems, and other x-ray tomography systems as well as numerous other medical imaging systems implementing an x-ray tube, such as x-ray or mammography systems.

FIG. **1** is a block diagram of an embodiment of an imaging system **10** designed both to acquire original image data and to process the image data for display and/or analysis in accordance with the present invention. It will be appreciated by those skilled in the art that the present invention is applicable to numerous medical imaging systems implementing an x-ray tube, such as x-ray or mammography systems. Other imaging systems such as computed tomography systems and digital radiography systems, which acquire image three dimensional data for a volume, also benefit from the present invention. The following discussion of x-ray system **10** is merely an example of one such implementation and is not intended to be limiting in terms of modality.

Referring to FIG. **1**, a computed tomography (CT) imaging system **10** is shown as including a gantry **12** representative of a “third generation” CT scanner. Gantry **12** has an x-ray tube assembly or x-ray source assembly **14** that projects a cone beam of x-rays toward a detector assembly or collimator **16** on the opposite side of the gantry **12**. Referring now to FIG. **2**, detector assembly **16** is formed by a plurality of detectors **18** and data acquisition systems (DAS) **20**. The plurality of detectors **18** sense the projected x-rays **22** that pass through a medical patient **24**, and DAS **20** converts the data to digital signals for subsequent processing. Each detector **18** produces an analog electrical signal that represents the intensity of an impinging x-ray beam and hence the attenuated beam as it passes through the patient **24**. During a scan to acquire x-ray projection data, gantry **12** and the components mounted thereon rotate about a center of rotation **26**.

Rotation of gantry **12** and the operation of x-ray source assembly **14** are governed by a control mechanism **28** of CT system **10**. Control mechanism **28** includes an x-ray controller **30** that provides power and timing signals to an x-ray source assembly **14** and a gantry motor controller **32** that controls the rotational speed and position of gantry **12**. An image reconstructor **34** receives sampled and digitized x-ray data from DAS **20** and performs high speed reconstruction. The reconstructed image is applied as an input to a computer **36** which stores the image in a mass storage device **38**. Computer **36** also has software stored thereon corresponding to electron beam positioning and magnetic field control, as described in detail below.

Computer **36** also receives commands and scanning parameters from an operator via console **40** that has some form of operator interface, such as a keyboard, mouse, voice activated controller, or any other suitable input apparatus. An associated display **42** allows the operator to observe the reconstructed image and other data from computer **36**. The operator supplied commands and parameters are used by computer **36** to provide control signals and information to DAS **20**, x-ray controller **30** and gantry motor controller **32**. In addition, computer **36** operates a table motor controller **44** which controls a motorized table **46** to position patient **24** and gantry **12**. Particularly, table **46** moves patient **24** through a gantry opening **48** of FIG. **1** in whole or in part.

FIG. **3** illustrates a cross-sectional view of x-ray tube assembly **14** according to an embodiment of the invention. X-ray tube assembly **14** includes an x-ray tube **50** that includes a vacuum chamber or enclosure **52** having a cathode assembly **54** positioned in a cathode portion **56** thereof. A rotating target **58** is positioned in a target portion **60** of vacuum enclosure or housing **52**. Cathode assembly **54** includes a number of separate elements, including a cathode cup (not shown) that supports a filament **62** and serves as an electrostatic lens that focuses a beam of electrons **64** emitted from heated filament **62** toward a surface **66** of target **58**. A stream of x-rays **68** is emitted from surface **66** of target **58** and is directed through a window **70** of vacuum enclosure **52**. A number of electrons **72** are backscattered from target **58** and impact and heat an inner surface **74** of vacuum enclosure **52**.

A coolant is circulated along an outer surface **76** of vacuum enclosure **52**, as illustrated by arrows **78**, **80** to mitigate heat generated in vacuum enclosure **52** by backscattered electrons **72**.

A magnetic assembly **82** is mounted in x-ray tube assembly **14** at a location near the path of electron beam **64** within a throat portion **84** of vacuum enclosure **52**, which is downstream from cathode portion **56** and upstream from target portion **60**. Magnetic assembly **82** includes a first coil assembly **86**. According to one embodiment, coil **86** is wound as a quadrupole and/or dipole magnetic assembly and is positioned over and around throat portion **84** of vacuum chamber **52** such that a magnetic field generated by coil **86** acts on electron beam **64**, causing electron beam **64** to deflect and move along either the x- and/or y-directions. The direction of movement of electron beam **64** is determined by the direction of current flow though coil **86**, which is controlled via a control circuit **88** coupled to coil **86**. According to another embodiment, coil **86** is configured to control a focal spot size or geometry. Optionally, a second coil assembly **90** (shown in phantom) may also be included in magnetic assembly **82**, as shown in FIG. **3**. Coil assemblies **86**, **90** may have dipole and/or quadrupole configurations, according to various embodiments and based on a desired electron beam control.

Embodiments of the invention set forth herein reduce the generation of eddy currents within the section of the x-ray tube throat **84** that is aligned with coil assemblies **86**, **90**, which allows the desired magnetic field to develop more rapidly. Eddy currents are developed in throat section **84** whenever the magnetic field is changing in magnitude, spatially or temporally. Eddy currents are not present when the magnetic field is unchanging. Consequently, the embodiments set forth herein are directed toward reducing the eddy current generation that would take place in a baseline metal throat section that is of a uniform cross-sectional thickness and volume, while simultaneously maintaining desired design specifications of throat section **84**. Such design specifications may be, for example, that throat section **84** is hermetic, structurally robust to resist atmospheric pressure and other applied forces, thermally robust to heating primarily due to backscattered electrons, electrically conducting on an inside surface to provide a conduction path for collected charge, and joinable to cathode section **56** and target section **60** of vacuum enclosure **52**.

FIG. **4** is an enlarged view of a subportion **92** of FIG. **3** that includes coil assembly **86** (FIG. **3**) and a throat wall **94** that is a portion of throat **84** of vacuum enclosure **52** (FIG. **3**), according to one embodiment of the invention. As shown, wall **94** of throat **84** includes a metal bellows **96** aligned with coil assembly **86**. Metal bellows **96** is designed having a length **98** corresponding to a magnetic field section **100** of wall **94**. Metal bellows **96** is joined with metal wall portions **102**, **104**. Metal bellows **96** has an inner diameter **110**, which is typically smaller than an inner diameter **112** of metal wall portions **102**, **104**, and an outer diameter **114**, which is typically larger than an outer diameter **116** of metal wall portions **102**, **104**.

The eddy current magnitude developed in throat section **84** is proportional to the amount of conducting material within the time-varying magnetic field. For a given magnet structure, the principle dimensional variable is the thickness of the throat. Due to its design, metal bellows **96** may be constructed with very thin wall sections (e.g., approximately 0.1-0.2 mm) and still support atmospheric pressure. Therefore, a thinner throat section will generate less eddy currents and result in a faster magnetic field rise rate. Also, because the sections of metal bellows **96** are more parallel to the magnetic flux lines generated by coil assembly **86**, eddy current development is decreased within magnetic field section **100**. According to one embodiment, a throat section **84** that includes a bellows **96** has been demonstrated to reduce the magnetic field rise time interior to throat section **84** be more than a factor of two as compared to a throat section having a uniform cross-sectional thickness that is able to support atmospheric pressure. However, the geometry of metal bellows **96** may result in degraded heat transfer to coolant flowing outside vacuum enclosure **52** due to dead zones that form at inner diameter roots **118** of bellows **96**.

While embodiments described with respect to FIG. **4** include one coil assembly, one skilled in the art will recognize that embodiments may be modified for an x-ray tube assembly having a pair of, or more, coil assemblies arranged along the length of throat section **84** for focusing the electron beam in length and width directions and deflecting the electron beam along two axes.

Referring to FIG. **5**, an enlarged view of subportion **92** of FIG. **3** is shown according to an alternative embodiment wherein throat portion **84** is constructed of a metal bellows **120** that extends along approximately the entire length of throat portion **84**. As such, an upstream end **122** of bellows **120** is joined to cathode portion **56** of x-ray tube **50** (FIG. **3**) and a downstream end **124** of bellows **120** is joined to target portion **60** of x-ray tube **50** (FIG. **3**). Optionally, subportion **92** may include a second coil assembly **90** (shown in phantom), positioned downstream of coil assembly **86**.

FIG. **6** is an enlarged view of subportion **92** of FIG. **3**, according to another multiple coil embodiment. As shown, throat portion **84** includes a first bellows **126** aligned with coil assembly **86** and a second bellows **128** aligned with coil assembly **90**. Wall portion **130** joins first bellows **126** with cathode portion **56** of vacuum chamber **52** (FIG. **3**), wall portion **132** joins first and second bellows **126**, **128**, and wall portion **134** joins second bellows **128** with target portion **60** of vacuum chamber **52** (FIG. **3**).

Referring now to FIGS. **4-6**, according to various embodiments wall portions **102**, **104**, **130**, **132**, and **134** and metal bellows **96**, **126**, **128** may be constructed of a non-ferromagnetic material having a high electrical resistivity to minimize eddy current development, including, for example, Molybdenum, stainless steel (austenitic stainless steels), titanium alloys, and the like. One skilled in the art will recognize that other materials of low electrical conductivity, high thermal conductivity and structural soundness may also be used.

Referring now to FIG. **7**, package/baggage inspection system **136** includes a rotatable gantry **138** having an opening **140** therein through which packages or pieces of baggage may pass. The rotatable gantry **138** houses a high frequency electromagnetic energy source **142** as well as a detector assembly **144** having detectors similar to those shown in FIG. **2**. A conveyor system **146** is also provided and includes a conveyor belt **148** supported by structure **150** to automatically and continuously pass packages or baggage pieces **152** through opening **140** to be scanned. Objects **152** are fed through opening **140** by conveyor belt **148**, imaging data is then acquired, and the conveyor belt **148** removes the packages **152** from opening **140** in a controlled and continuous manner. As a result, postal inspectors, baggage handlers, and other security personnel may non-invasively inspect the contents of packages **152** for explosives, knives, guns, contraband, etc.

Therefore, in accordance with one embodiment, an x-ray tube assembly includes a vacuum enclosure that has a cathode portion, a target portion, and a throat portion. The throat portion includes a metal bellows. An upstream end of the throat portion is coupled to the cathode portion and a downstream end of the throat portion is coupled to the target portion. The x-ray tube assembly also includes a target positioned within the target portion of the vacuum enclosure, and a cathode positioned within the cathode portion of the vacuum enclosure. The cathode is configured to emit a stream of electrons through the throat portion toward the target.

In accordance with another embodiment, an x-ray tube assembly includes a housing having a vacuum formed therein. The housing has a cathode portion, a target portion, and a throat portion that includes a bellows section. The x-ray tube assembly further includes a target positioned in the target portion of the vacuum housing, and a cathode positioned in the cathode portion of the vacuum housing to direct a stream of electrons toward the target.

In accordance with yet another embodiment, an imaging system includes a rotatable gantry having an opening therein for receiving an object to be scanned, a table positioned within the opening of the gantry and moveable through the opening, and an x-ray tube coupled to the gantry. The x-ray tube includes a vacuum chamber that has a target portion housing a target, a cathode portion housing a cathode, and a throat portion comprising a first bellows. The throat portion forms a passageway between the cathode portion and the target portion for a stream of electrons emitted from the cathode. The imaging system also includes a first electron manipulation coil mounted on the x-ray tube and aligned with the bellows. The first electron manipulation coil is configured to generate a first magnetic field within the throat portion to manipulate the stream of electrons therein.

This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the 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 skilled 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.

What is claimed is:

1. An x-ray tube assembly comprising:
- a vacuum enclosure comprising:
  - a cathode portion;
  - a target portion; and
  - a throat portion comprising a metal bellows, the throat portion having an upstream end coupled to the cathode portion and a downstream end coupled to the target portion;
- a target positioned within the target portion of the vacuum enclosure; and
- a cathode positioned within the cathode portion of the vacuum enclosure, the cathode configured to emit a stream of electrons through the throat portion toward the target.

2. The x-ray tube assembly of claim **1** wherein the throat portion has a length defined by a distance between the upstream end and the downstream end; and
- wherein the metal bellows has a length approximately equal to the length of the throat portion.

3. The x-ray tube assembly of claim **1** wherein the throat portion further comprises:
- an upstream section;
- a downstream section; and
- a magnetic field section mechanically coupled between the upstream section and the downstream section, the magnetic field section comprising the metal bellows; and
- wherein a susceptibility of the upstream and downstream sections to generate eddy currents is greater than a susceptibility of the magnetic field section to generate eddy currents.

4. The x-ray tube assembly of claim **3** wherein the metal bellows has an interior diameter that is smaller than an interior diameter of the upstream and downstream sections of the throat portion.

5. The x-ray tube assembly of claim **1** wherein the throat portion further comprises a second metal bellows.

6. The x-ray tube assembly of claim **1** wherein the metal bellows comprises a non-ferromagnetic material.

7. An x-ray tube assembly comprising:
- a housing having a vacuum formed therein, the housing comprising:
  - a cathode portion;
  - a target portion; and
  - a throat portion comprising a bellows section coupled to the cathode portion and the target portion; and
- a target positioned in the target portion of the vacuum housing; and
- a cathode positioned in the cathode portion of the vacuum housing to direct a stream of electrons toward the target.

8. The x-ray tube assembly of claim **7** further comprising a first electromagnetic coil positioned around the throat portion of the housing and aligned with the bellows, the first electromagnetic coil configured to generate a first magnetic field having a maximum magnetic flux density in the bellows section of the throat portion.

9. The x-ray tube assembly of claim **8** further comprising a second electromagnetic coil positioned around the throat portion of the housing and aligned with the bellows, wherein the second electromagnetic coil is configured to generate a second magnetic field having a maximum magnetic flux density in the bellows section of the throat portion.

10. The x-ray tube assembly of claim **8** wherein the bellows section of the throat portion has a length approximately equal to a length of the throat portion.

11. The x-ray tube assembly of claim **7** wherein the throat portion further comprises:
- a first section positioned upstream of the bellows section, the first section having a wall thickness substantially equal to a wall thickness of the cathode portion of the housing; and
- a second section positioned downstream of the bellows section, the second section having a wall thickness substantially equal to a wall thickness of the target portion of the housing.

12. The x-ray tube assembly of claim **11** wherein the bellows section has an interior diameter that is smaller than an interior diameter of the first and section sections of the throat portion.

13. The x-ray tube assembly of claim **7** wherein the bellows comprises a non-ferromagnetic metal.

14. An imaging system comprising:
- a rotatable gantry having an opening therein for receiving an object to be scanned;
- a table positioned within the opening of the gantry and moveable through the opening;
- an x-ray tube coupled to the gantry, the x-ray tube comprising:
  - a vacuum chamber comprising:
    - a target portion housing a target;
    - a cathode portion housing a cathode; and

a throat portion comprising a first bellows, the throat portion forming a passageway between the cathode portion and the target portion for a stream of electrons emitted from the cathode; and

a first electron manipulation coil mounted on the x-ray tube and aligned with the bellows, the first electron manipulation coil configured to generate a first magnetic field within the throat portion to manipulate the stream of electrons therein.

15. The imaging system of claim **14** further comprising a second electron manipulation coil mounted on the x-ray tube adjacent to the first electron manipulation coil, the second electron manipulation coil configured to generate a second magnetic field within the throat portion to manipulate the stream of electrons therein.

16. The imaging system of claim **15** wherein the second electron manipulation coil is aligned with the first bellows.

17. The imaging system of claim **15** wherein the throat portion further comprises a second bellows positioned downstream of the first bellows; and

wherein the second electron manipulation coil is aligned with the second bellows.

18. The imaging system of claim **14** wherein the first bellows comprises a non-ferromagnetic metal.

19. The imaging system of claim **18** wherein the first bellows comprises one of Molybdenum, stainless steel, and a titanium alloy.

20. The imaging system of claim **14** wherein the first bellows has a length substantially equal to a length of the throat portion.

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