(12) STANDARD PATENT APPLICATION (11) Application No. **AU 2016201678 A1**
(19) AUSTRALIAN PATENT OFFICE

(54) Title
On-belt analyser system

(51) International Patent Classification(s)
G01N 33/24 (2006.01) ***G01N 23/222*** (2006.01)

(21) Application No: **2016201678** (22) Date of Filing: **2016.03.16**

(43) Publication Date: **2016.06.09**
(43) Publication Journal Date: **2016.06.09**

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2012227259

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2016201678 16 Mar 2016

ABSTRACT

A bulk material analyser configured to analyse bulk material in the form of coal, minerals, cement raw materials, or the like, including:

an enclosed tunnel for receiving a conveyor belt carrying a bulk material to be analysed, the enclosed tunnel having a roof, a base and walls that together form a closed loop around the conveyor belt;

a neutron source to emit neutrons into the material in the tunnel for interaction with the material disposed therein; and

a gamma ray detector to detect gamma rays emitted from the material in response to the neutron interaction;

wherein the conveyor belt passes through the tunnel in an elevated position relative to the base of the tunnel.

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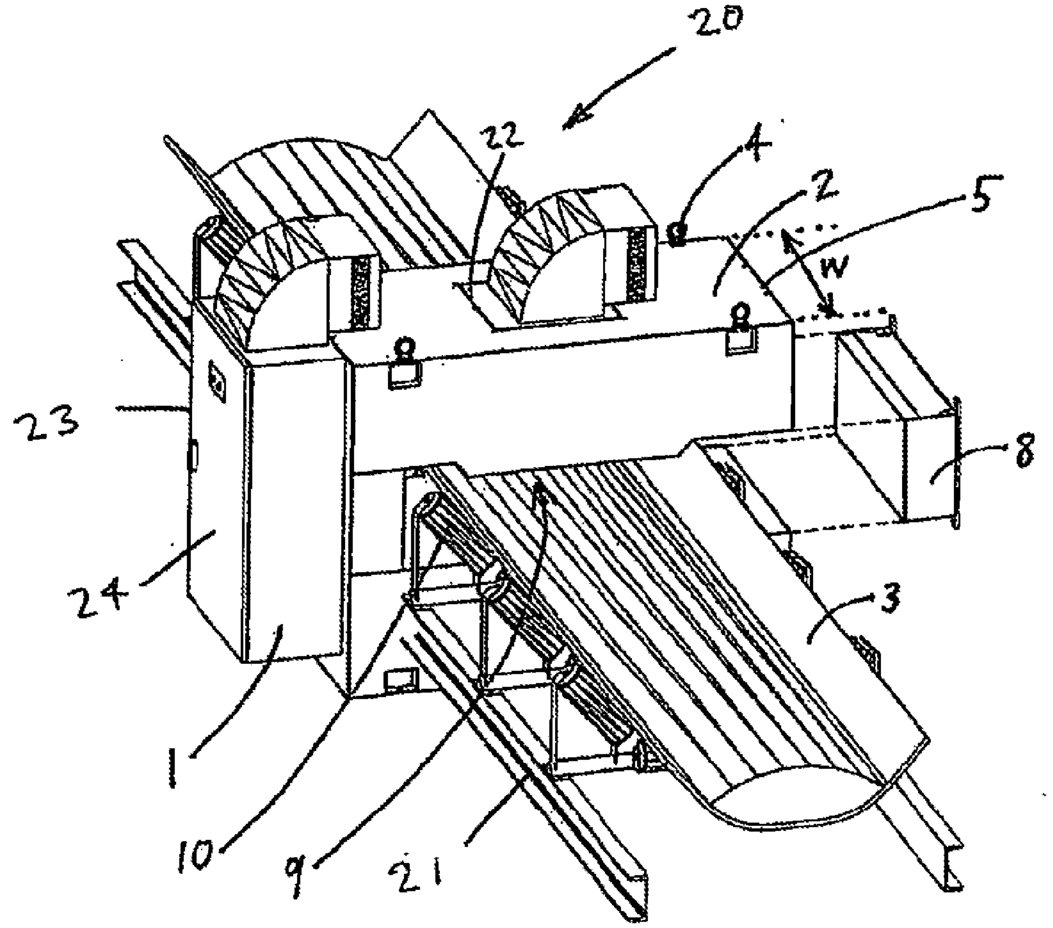

Figure 1

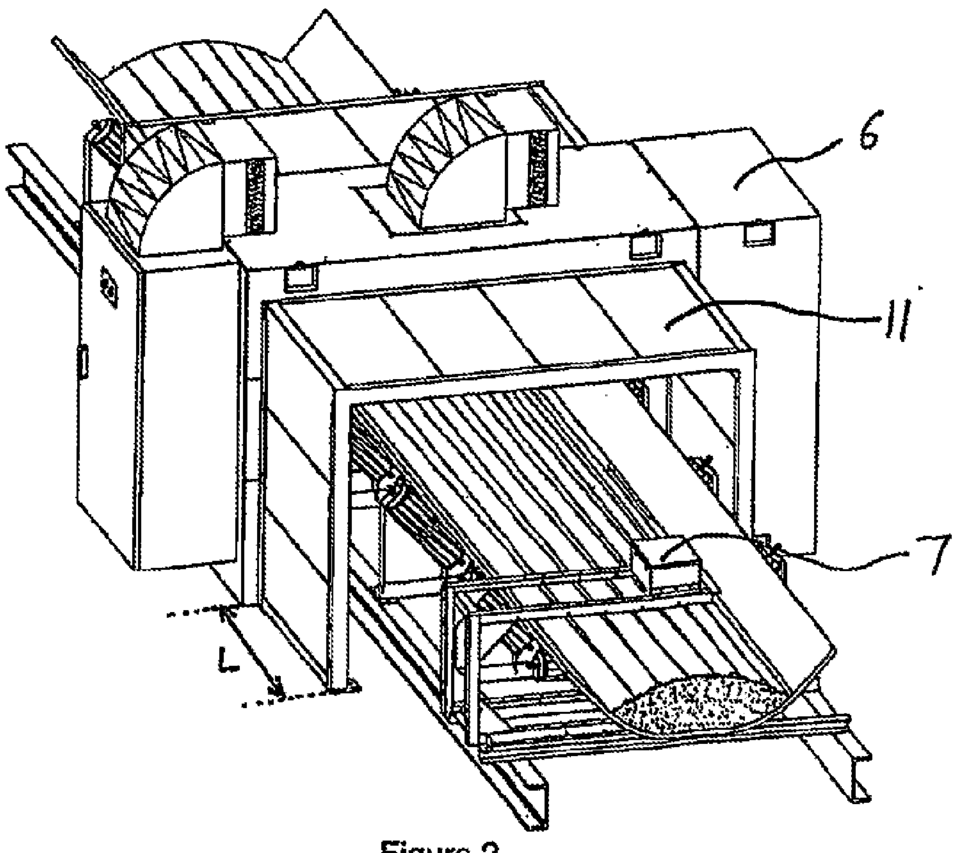

Figure 2

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ON-BELT ANALYSER SYSTEM

Related Applications

This application claims priority from Australian Provisional Patent Application No. 2005900951 and United States Provisional Patent Application No. 60/658195, the contents of which are incorporated herein by reference.

Technical Field

This invention relates to a bulk material analyser configured to analyse bulk material in the form of coal, minerals, cement raw materials, or the like.

Background

One form of on-belt analyser, which utilises a thermal neutron capture and gamma ray production technique known as PGNAA (Prompt Gamma Neutron Activation Analysis), is employed to analyse the composition of material such as coal or other mineral product transported on a conveyor belt. The analyser has a C-shaped housing provided with lifting points to allow the analyser to be appropriately positioned across a path of the belt. The weight of the analyser is quite substantial, in the order of 6500 to 9000 kg and the lifting points are necessarily provided at a base of the analyser due to structural load-bearing limitations of the housing. Once positioned, removable side shielding is fitted to close the open side of the C-shaped housing, to thereby define a tunnel in the order of 2 meters long, through which the belt passes. Tunnel slider panels support the belt as it passes through the analyser.

Installation and operating costs of the analyser are relatively high given the analyser generally needs to be installed in a shed or the like for protection from the elements and various component parts such as the slider panels are subject to wear during operation. Also, in order to install the analyser substantial parts of the conveyor belt support structure, such as frame work and stringer or idler wheels, need to be removed. The remaining structure, at either side of the analyser, then needs to be configured in order to ensure an appropriate profile is applied to the conveyor belt, as it enters the analyser, compatible with the shape of the tunnel and the slider panels.

It is desired, to provide a bulk material analyser that alleviates one or more difficulties of the prior art, or that to least provide a useful alternative.

Summary

In accordance with some embodiments of the present invention, there is provided a bulk material analyser configured to analyse bulk material in the form of coal, minerals, cement raw materials, or the like, including:

an enclosed tunnel for receiving a conveyor belt carrying a bulk material to be analysed, the enclosed tunnel having a roof, a base and walls that together form a closed loop around the conveyor belt;

a neutron source to emit neutrons into the material in the tunnel for interaction with the material disposed therein; and

a gamma ray detector to detect gamma rays emitted from the material in response to the neutron interaction;

wherein the conveyor belt passes through the tunnel in an elevated position relative to the base of the tunnel.

In accordance with some embodiments of the present invention, there is provided a bulk material analyser configured to analyse bulk material in the form of coal, minerals, cement raw materials, or the like, carried on a conveyor belt, the analyser including:

an enclosed tunnel for receiving the conveyor belt, the enclosed tunnel having a roof, a base and walls that together form a closed loop around the conveyor belt when installed;

a neutron source to emit neutrons into the material in the tunnel for interaction with the material disposed therein; and at least one gamma ray detector to detect gamma rays emitted from the material in response to the neutron interaction;

wherein the analyser is configured to allow the conveyor belt to travel through the tunnel, in use, in an elevated position relative to the base of the tunnel.

In some embodiments, the bulk material analyser is configured to allow the conveyor belt to travel through the tunnel in freely suspended relation so that neither the belt nor the base of the tunnel is subject to wear within the tunnel.

In accordance with some embodiments of the present invention, there is provided a bulk material analyser configured to analyse bulk material in the form of coal, minerals, cement raw materials, or the like, and being adapted to be positioned across a path of a conveyor belt which carries bulk material to be analysed, the analyser including a neutron source and at least one gamma ray detector, wherein the analyser defines an enclosed tunnel, and the conveyor belt carrying bulk material to be analysed in use passes between the neutron source and the gamma ray detector and through the tunnel in an elevated position relative to a base of the tunnel.

In accordance with some embodiments of the present invention, there is provided a bulk material analyser configured to analyse bulk material in the form of coal, minerals, cement raw materials, or the like, including a neutron source, at least one gamma ray detector, wherein the analyser defines an enclosed tunnel and is adapted to be positioned across a path of a conveyor belt which carries bulk material to be analysed, such that in use the belt passes between the neutron source and the gamma ray detector and through the tunnel in an elevated position relative to a base of the tunnel, the portion of the conveyor belt within the tunnel being suspended between supports external of the tunnel.

In some embodiments, the bulk material analyser is adapted to be positioned across a path of an existing conveyor belt without disrupting the existing conveyor belt.

In some embodiments, the analyser includes a C-shaped portion and a removable side portion to close the open side of the C-shaped portion and thereby define the enclosed tunnel and allowing the analyser to be retro-fitted across a bulk material conveyor belt.

In some embodiments, the enclosed tunnel is configured to receive a belt of between 600 mm and 1400 mm in width, with a trough angle of between 30° and 45° without requiring any modification to the belt profile.

In some embodiments, the bulk material analyser includes a conveyor assembly with idlers arranged to support the belt at either side of the enclosed tunnel so as to suspend the belt in an elevated position relative to the base of the enclosed tunnel as the belt passes through the tunnel. In some embodiments, the idlers are spaced at between 1.2 and 1.5 metres apart.

In some embodiments, the width of the analyser, in a direction lengthwise of the conveyor belt, is in the order of 1 metre.

In some embodiments, the bulk material analyser is arranged whereby a clearance in the order of 30 mm is provided between the belt carrying bulk material and a base of the tunnel.

In some embodiments, the bulk material analyser includes extension panels to provide protection adjacent to the analyser and external of the enclosed tunnel, from radiation emissions generated by the neutron source within the analyser.

In accordance with some embodiments of the present invention, there is provided a bulk material analyser configured to analyse bulk material in the form of coal, minerals, cement raw materials, or the like, including:

an enclosed tunnel for receiving a conveyor belt carrying a bulk material to be analysed, the enclosed tunnel having a base and walls that together form a closed loop around the conveyor belt;

a neutron source to emit neutrons into an interaction region within the enclosed tunnel for interaction with a bulk material disposed therein; and at least one gamma ray detector to detect gamma rays emitted from the material in response to the neutron interaction;

wherein the conveyor belt carrying the bulk material passes through the enclosed tunnel in an elevated position relative to the base of the tunnel.

In accordance with some embodiments of the present invention, there is provided a bulk material analyser configured to analyse bulk material in the form of coal, minerals, cement raw materials, or the like, including:

an enclosed tunnel for receiving a conveyor belt carrying a bulk material to be analysed, the enclosed tunnel having a base and walls that together form a closed loop around the conveyor belt when installed;

a neutron source to emit neutrons into an interaction region within the enclosed tunnel for interaction with a bulk material disposed therein; and

at least one gamma ray detector to detect gamma rays emitted from the material in response to the neutron interaction;

wherein the analyser is configured to allow the conveyor belt carrying the bulk material to travel through the enclosed tunnel in an elevated position relative to the base of the tunnel.

In some embodiments, the conveyor belt carrying the bulk material is unsupported between the neutron source and the at least one gamma ray detector.

In some embodiments, the conveyor belt carrying the bulk material is unsupported throughout the interaction region.

In some embodiments, the bulk material analyser includes lifting points at an upper section of the housing.

In some embodiments, the lifting points are provided by eye-bolts.

In some embodiments, the bulk material analyser includes a canopy for protecting the analyser, the canopy being attached to the lifting points.

In some embodiments, the neutron source and detector are configured for analysis using Prompt Gamma Neutron Activation Analysis (PGNAA).

In some embodiments, the bulk material analyser includes multi-channel analyser electronics, wherein the gamma-ray detector and the multi-channel analyser electronics are located within a common air-conditioned, temperature-controlled detector enclosure.

In some embodiments, the neutron source is disposed below the conveyor belt, and the gamma ray detector is disposed above the conveyor belt.

In some embodiments, the bulk material analyser includes the analyser includes a housing that defines the enclosed tunnel.

Also described herein is a bulk material analyser configured to analyse bulk material in the form of coal, minerals, cement raw materials, or the like, including:

a housing defining an enclosed tunnel for receiving a conveyor belt carrying a bulk material to be analysed;

a neutron source to emit neutrons into the material in the tunnel for interaction with the material disposed therein; and

a gamma ray detector to detect gamma rays emitted from the material in response to the neutron interaction;

wherein the conveyor belt is unsupported by the analyser within the tunnel.

Also described herein is a bulk material analyser configured to analyse bulk material in the form of coal, minerals, cement raw materials, or the like, including a neutron source, a gamma ray detector, and a housing adapted to be positioned across a path of a conveyor belt which carries bulk material to be analysed, wherein the housing defines an enclosed tunnel dimensioned to allow the belt to pass between the neutron source and the gamma ray detector and through the tunnel without being supported within the tunnel.

Also described herein is a bulk material analyser configured to analyse bulk material in the form of coal, minerals, cement raw materials, or the like, including a neutron source, a detector, and a housing adapted to be positioned across a path of a conveyor belt which carries bulk material to be analysed, wherein the housing defines an enclosed tunnel dimensioned to allow the belt to pass between the neutron source and the gamma ray detector and through the tunnel without being supported within the tunnel so that the portion of the belt within the tunnel can be suspended between support idlers external of the tunnel.

Also described herein is a bulk material analyser configured to analyse bulk material in the form of coal, minerals, cement raw materials, or the like, including:

a housing defining an enclosed tunnel for receiving a conveyor belt carrying a bulk material to be analysed;

a neutron source to emit neutrons into an interaction region within the enclosed tunnel for interaction with a bulk material disposed therein; and

a gamma ray detector to detect gamma rays emitted from the material in response to the neutron interaction;

wherein a conveyor belt carrying the material is unsupported in the interaction region so as not to be subject to wear in the interaction region.

Also described herein is an analyser with a C-shaped housing which allows the housing to be retro-fitted across a bulk material conveyor belt, wherein the housing defines a tunnel dimensioned to allow the belt to travel therethrough in freely suspended relation in order to allow analysis of material carried on the belt, without the belt being supported by the housing in the tunnel.

Also described herein is an analyser system including a PGNAA analyser having a housing adapted to be positioned across a path of a conveyor belt which carries material to be analysed, wherein the housing defines a tunnel dimensioned to allow the belt to pass through the tunnel without being supported by tunnel slider panels.

Also described herein is an analyser system including a PGNAA analyser having a housing adapted to be positioned across a path of a conveyor belt which carries material to be analysed, wherein the conveyor belt forms part of a conveyor assembly and the housing

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defines a tunnel dimensioned to allow the analyser to be positioned between existing belt-supporting structure of the conveyor assembly

Also described herein is an analyser with a housing adapted to be positioned across a path of a conveyor belt and a canopy for protecting the housing.

The canopy may be fitted to lifting points located on an upper arm of the housing.

The housing defines an enclosed tunnel through which the conveyor belt passes and may have extension panels fitted thereto to provide protection adjacent the analyser and external of the tunnel, from radiation emissions generated from a radiation source within the analyser.

Brief Description of the Drawings

Some embodiments of the present invention are herein described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Figure 1 is a perspective view of an analyser in accordance with an embodiment of the present invention;
Figure 2 is a perspective view of the analyser of Figure 1, fitted with extension panels, automatic source drive shield, and canopy;
Figure 3 is a cross-sectional view of the analyser;
Figure 4 is a diagrammatic end view of the analyser with a canopy;
Figure 5 includes cross-sectional side views of a source storage drum and a source rod of the analyser;
Figures 6 to 11 are schematic illustrations of the analyser, showing reference points for the radiation measurements documented in Appendix II;
Figures 12 and 13 are schematic cross-sectional side and top views, respectively, of the source storage drum, showing reference points for the radiation measurements documented in Appendix II;

Figures 14 and 15 are photographic images of a radiation warning sign and a radioactive source identification plate of the analyser, respectively;
Figure 16 is a schematic diagram of a shielding test sample used in the fire test described in Appendix II;
Figure 17 is a chart record of furnace temperature during the fire test;
Figures 18 to 24 are photographic images of the shielding test sample, prior to the fire test (Figure 18), on removal from the furnace (Figure 19), two minutes after removal from the furnace (Figures 20 and 21), with its lid removed (Figures 22, 23 and 24, the latter images showing unmelted CNS);
Figures 25 and 26 are cross-sectional side views of a source storage drum and a source rod of the analyser, respectively;
Figures 27 and 28 are schematic side views of the analyser, showing reference points for the radiation survey documented in Appendix II.E;
Figures 29 to 35 are schematic views of the analyser, showing reference points for the radiation survey (analyser with automatic source drive option) documented in Appendix II.F;
Figures 35 is an illustration of the described on belt analyser in isolation;
Figure 36 is the same as Figure 35, but showing dimensions of one embodiment; and
Figure 37 is an illustration of a calibration container used to verify the analyser calibration.

Detailed Description

An analyser system 20 is shown in Figure 1 as including an analyser 1 and a conveyor assembly 21. In order to facilitate installation of the analyser 1, the analyser 1 is configured so that one of its side shielding portions 8 can be removed during installation. The analyser 1 thus has a C-shaped housing portion 2 arranged to be positioned across a path of a conveyor belt 3 of the assembly 21. The analyser 1 is designed so as to weigh only in the order of 2000 kg which is light enough for the C-shaped housing portion 2 to maintain structural integrity even if lifted from lifting points 4 provided by eye-bolts, which are provided on an upper arm 5 of the analyser 1. For that purpose, the analyser 1 is preferably formed of a steel framed enclosure or housing filled with cast neutron shielding

(CNS). The CNS is a dense suspension of 60% high-density polyethylene beads cemented together with a mixture of 20% borax and 20% polyester resin-plus catalyst. This material provides most of the shielding required since it is effective in slowing down and absorbing neutrons. The material is also waterproof, non-corrosive and intrinsically fire resistant.

Once the analyser 1 is positioned in the manner shown, the removable side shielding portion 8 is fastened in place so that the analyser defines a tunnel 9 through which the belt 3 passes. A width dimension "w" of the analyser is preferably in the order of 1 metre to allow the analyser to be positioned between existing supporting structure, such as idlers 10, of the conveyor assembly 21, which are conventionally spaced at between 1.2 and 1.5 metres apart.

In some circumstances, it may be necessary to provide additional shielding for radiation protection and, in that case, a further side shield 6 may be provided and extension panels 11 may be fitted either side of the tunnel, as shown in Figure 2. The extension panels are preferably formed of UV stabilised polyethylene or like material, which is suitable for absorbing radiation from, for example, a Cf-252 source. The panels 11 may be dimensioned so as to provide protection for an additional length "L" of, say, 1 metre either side of the analyser 1.

Figure 2 also shows the system 20 as including an optional microwave moisture content analyser 7 positioned above the belt 3.

Referring now to Figure 3, a cross-section of the analyser 1 is shown in detail with the side shielding portion 8 attached to the C-shaped housing portion 2, so as to define the tunnel 9. The tunnel 9 is an enclosed tunnel because it forms a closed loop around the conveyor belt 3 (*i.e.*, it fully encircles the belt 3 and is continuous with no openings or gaps when viewed in cross-section as shown in Figure 3). Both the C-shaped portion 2 and the side shielding portion 8 are filled with cast neutron shielding and are parts of the analyser enclosure or housing.

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A radiation source 12 is provided in a base 13 of the tunnel and detectors 14 are appropriately located above the tunnel 9. The tunnel 9 is positioned and dimensioned so as to receive the conveyor belt 3 in an elevated position relative to the base 13 of the tunnel 9. The clearance is preferably in the order of 30 mm to allow for a slight droop in the belt 3 between its supporting idlers 10. Previously, it was considered critical to minimise the distance between the Cf-252 source and material to be analysed in order to maximise absorption of neutrons in the material. Accordingly, the prior-art analyser was designed to have contact between the belt and the analyser using 25 mm thick slider panels. The geometry of the analyser illustrated in Figure 3, however, has been investigated using a program called MCNP (Monte Carlo N-particle) and it has been found that replacing the slider panels with air made little difference. Accordingly, a clearance is provided between the belt 3 and the base 13 of the tunnel 9, which allows the previous slider panels to be dispensed with, thereby reducing construction and maintenance costs. The tunnel 9 is shaped to accommodate conveyor belts 3 from 600 mm to 1400 mm wide with trough angles from 30° to 45° with no modification to belt 3 or tunnel 9. As a result of the relative clearance, an additional advantage is realised in that belt clips and staples (not shown) can not damage analyser 1.

Turning now to Figure 4, the analyser 1 is shown with a canopy 15 supported on struts 16 fixed to the lifting points 4. The canopy 15 is preferably formed of 3 mm thick steel or fibreglass and stands approximately 400 mm above the analyser 1, leaving an approximate clearing of 50 mm above the 350 mm high air conditioners 17. The canopy 15 provides protection to the top 18 of the analyser 1 from direct sunlight, rain and snow. The canopy 15 should also minimise dust build-up on and around the air conditioner 17. Provision of the canopy 15 additionally allows the analyser to be installed in an external environment at any desired location along the length of the conveyor belt 3, as compared to the prior art analyser, which needed to be installed within a shed. As such, the analyser 1 provides for further reduction in installation costs.

In addition to the above, the prior-art analyser used proprietary analogue electronics and NaI (sodium iodide crystal) detectors. The present analyser 1, on the other hand, uses off-the-shelf digital multi-channel analysers and bismuth germinate crystal (BGO) detectors.

The digital multi-channel analysers provide more consistent, linear, stable spectra and are more reliable as compared to the previous analyser electronics, for which components are becoming obsolete. The BGO detectors capture more gamma rays and have better photo-peak fraction due to higher crystal density, have better peak to background ratio (i.e. better signal-to-noise ratio) and better linearity. The detectors 14 and associated multi-channel analyser electronics are preferably located within a single common air-conditioned, temperature-controlled detector enclosure 22 to simplify operational and construction requirements. The remaining electronics such as an analyser computer and other electronics modules are likewise located within a single air-conditioned, temperature-controlled electronics cabinet 23, which has a sealed and locked door 24.

As such, the above-described analyser 1 provides a number of advantages over the prior-art analyser, which result from internal componentry, reduced weight and dimensions, as well as the provision of a canopy and the clearance between the analyser and a conveyor belt passing through the analyser tunnel. As may be appreciated then, the analyser may be installed on an existing conveyor assembly with minimal modification or removal of steel work of the belt support structure since the analyser is of a width sufficient to fit between pre-existing idlers and does not contact the belt so the supporting structure does not need to be configured in any particular fashion necessary to form a specific belt profile suitable for the tunnel, as compared to the prior-art analyser arrangement.

Further and more particular details of a preferred form of analyser and its installation are provided in Applicant's publications "On Belt Analyser Operation & Maintenance Manual" Version 1.3, September 2005; "On Belt Analyser-5 Health & Safety Review" Version 1.6, February 2006; and "On Belt Analyser Installation Manual" Version 7.3, October 2005, the contents of which are provided in the Appendices.

Some embodiments of the invention have been described, by way of non-limiting example only, and many modifications and variations may be made thereto, without departing from the scope of the invention.

The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that that prior publication (or information derived from it) or known matter forms part of the common general knowledge in the field of endeavour to which this specification relates.

APPENDIX I

On Belt Analyser

Operation & Maintenance Manual

Version 1.3

September 2005

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Version 1.3
September 2005

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About this manual

Who should use this manual?

This manual is intended for the operators of the "Geoscan" and "Coalscan Model 9500X" On Belt Analyser. It contains:

- an introduction to the On Belt Analyser
- component descriptions
- operating and maintenance instructions
- fault-finding information
- safety information

Conventions

This manual uses the following symbols and conventions:

Symbol	Description
1. 2. ...	steps in a procedure
Italics	the name of a screen or window
Bold	button or field
❑	end of a procedure
☞	indicates a note
⧗	indicates a waiting period
CAUTION	indicates a situation where the equipment could be damaged or return unreliable data
WARNING	indicates a situation where the safety of personnel may need to be considered.

Related documents

1. On Belt Analyser Installation Manual
2. On Belt Analyser Health and Safety Review

1 General Description

This chapter contains a brief introduction to the On Belt Analyser and an overview of components. It contains the following sections:

◊ Introducing the On Belt Analyser

◊ Theory of operation

1.1 Introducing the On Belt Analyser

The On Belt Analyser measures the elemental composition of material as it passes through the analyser on a conveyor belt. It can be used for coal, cement or minerals applications.

Measurements are made on-line and real-time results are obtained. Results are produced as frequently as every 1 minute and are available via a Modbus TCP/IP or optical fibre connection to a plant PLC / SCADA system, or an optional superSCAN computer.

1.2 Theory of operation

The On Belt Analyser incorporates the Prompt Gamma Neutron Activation Analysis (PGNAA) technique for measuring gamma rays produced by the absorption of thermal neutrons in material.

1.2.1 Elemental analysis

Neutron source and gamma ray production

A neutron source (Californium–252) inside the analyser emits neutrons that irradiate the conveyed material that passes through the On Belt Analyser. Thermal neutrons are captured by the nuclei of the various elements in the material, which then become highly 'excited', i.e. they contain excess energy. This energy is instantly radiated away from the nucleus by the emission of several gamma rays, each with a distinct energy.

This technique of analysing materials by thermal neutron capture and gamma ray production is known as PGNAA. It relies on the elements producing characteristic and discrete gamma ray energies which are unique to each nuclear species. For example, the energy and number of gamma rays emitted when a calcium nucleus captures a neutron are completely different to those emitted by a silicon nucleus. The elemental composition can be interpreted from the measured gamma ray spectrum.

The gamma ray spectrum is extremely complex because some elements capture thermal neutrons more readily than others, and even those that readily capture neutrons may emit gamma rays of many different energies and intensities.

1.2.2 Moisture analysis

Moisture content can be computed from either the PGNAA Hydrogen measurement or input from an optional microwave moisture gauge.

2 Components

This chapter describes the On Belt Analyser components.

2.1 Standard components

Analyser

The analyser is a painted corrosion resistant steel frame containing:

- Cf-252 neutron source
- approved neutron source holder
- neutron reflectors/moderators
- radiation shielding
- detector assembly (detectors and digital multi-channel analyser electronics)
- detector air conditioner

Tunnel extensions

UV-resistant polyethylene blocks in a channel-section steel frame.

Electronics cabinet

Attached to the analyser is a lockable IP66 rated stainless steel cabinet containing:

- analyser computer
- input/output modules
- electronics air conditioner
- uninterruptible power supply (UPS)
- lockable radioactive source access
- modem
- transient protectors, circuit breakers and power supplies

Remote diagnostic access

The modem requires a dedicated customer-supplied telephone line.

2.2 Optional components

SCADA Computer—SuperSCAN

The following components comprise the optional SuperSCAN computer package:

- Pentium PC, including mouse and keyboard
- 15" SVGA monitor
- Inkjet printer
- Ethernet card
- iFIX SCADA software package.

The following features are part of the standard superSCAN package:

- Instantaneous analysis
- Accumulative average analysis
- Rolling average analysis
- Alarms and event logging
- Historical trending
- Analyser status.

Microwave moisture gauge

The optional microwave moisture gauge is a C-shaped frame installed on the conveyor belt within 5 metres of the On Belt Analyser. It outputs serial data strings to the analyser computer for accurate calculation of moisture in the material.

Automatic source drive assembly

The automatic source drive is comprised of:

- Source drive motor installed in the electronics cabinet
- Additional radiation shielding installed at the rear of the analyser

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2.3 Functionality of components

2.3.1 Analyser computer

The Analyser computer is a Pentium PC located in the electronics cabinet. Its functions are to:

- read spectra from the digital multi-channel analysers in the detector enclosure, read the data from the optional microwave moisture system and communicate with the input/output modules.
- calculate analysis results when required and output them to the optional superSCAN computer or plant system via a Modbus TCP/IP or optical fibre connection
- maintain parameters for the calibration equations and analyser configuration
- maintain analysis result accumulators containing cumulative analysis results and raw data
- perform standardisation when the conveyor belt runs empty.

Standardisation compensates for natural drift in detector non-linearity and conveyor belt wear.

The analyser computer has two operating modes:

- ANALYSE
- STANDARDISE.

2.3.2 Spectrometer

The spectrometer is comprised of scintillation detectors and digital multi- channel analysers (DMCAs). The detectors capture gamma rays and convert them into analogue pulses. The DMCAs convert the analogue pulses into digital signals and sort them into spectra channels.

The On Belt Analyser incorporates a proprietary multi-detector array with digital electronics.

The spectrometer collects a spectrum for each detector and combines them into one resultant spectrum for each result calculation. The spectrometer has the following advantages:

- the multi-detector array copes in the unlikely event of detector damage or failure
- results in a more stable calibration, valid over a wide range of material types
- allows the analyser to operate with a higher tunnel ceiling than found in conventional systems.

2.3.3 Temperature control electronics

Electronics cabinet

The electronics cabinet has a solid state air conditioner that maintains an internal air temperature of 30°C. It uses a Peltier device for cooling and a resistive heater element for heating, both under PID control.

The air conditioner has a 45°C over-temperature cut off.

Detector enclosure

The detectors in the upper section have an identical solid state air conditioner that maintains an internal air temperature of 20°C.

The air conditioner has a 45°C over-temperature cut off.

2.3.4 Input/Output modules

The ADAM input/output modules plug into an ADAM-5000/485 base and facilitate communication with the plant and other devices in within the analyser using the following modules:

- ADAM-5051D – 16 Digital Input module
- ADAM-5068 – Relay Output module
- ADAM-5017H – Analogue Input module which has 4-20mA current loop inputs and converts the signal to digital
- ADAM-5013 – Temperature Input module which has 3 PT100 probe inputs and converts the signal to digital

A separate ADAM-6521 Ethernet Hub provides Ethernet and Optical Fibre Modbus output to the plant or superSCAN system.

2.3.5 Mains power supply

The following power supply must be connected to the incoming mains terminal. The cable entry points are at the bottom of the electronics cabinet.

Mains Supply: 20 A

240 VAC, +10% / –15%

Momentary power failure less than 10 msec

50/60 Hz ± 1 Hz

Less than 5% total harmonic distortion

Less than 3% any single harmonic distortion

A continuous power supply ensures optimum operation of the analyser. Even when the analyser is not analysing material, stabilisation processes, which take place on the empty belt, would be upset by power interruptions. When selecting the power circuit, the most reliable circuit should be chosen.

The On Belt Analyser is equipped with an uninterruptible power supply (UPS). The UPS protects sensitive components in the analyser from power problems such as power failures, power drops and surges, and line noise.

2.4 Communications

2.4.1 Connecting to the Analyser computer

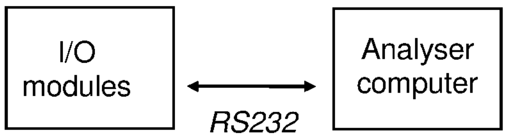
The Analyser computer can be accessed using a computer running PC Anywhere in the following ways:

- connecting a laptop to the service port on the side of the electronics cabinet using a standard Ethernet cable, or
- dialling the analyser computer's external modem.

Normally this is only required by Scantech service engineers for performing software upgrades, routine maintenance, calibration and fault finding procedures.

Login names and passwords prevent unauthorised access at the remote login.

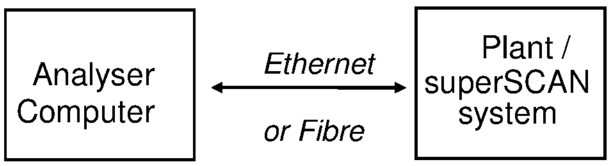
2.4.2 Input/Output modules—Analyser computer



The analyser computer communicates with the I/O modules and initiates all communications between the two components.

A standard straight-through RS232 cable is used.

2.4.3 Analyser computer—Plant/SuperSCAN system



The Analyser computer can be configured as a Server or Client. In Server mode data is sent when requested by the SCADA system. In Client mode data is sent periodically to the SCADA system.

Communication is by an Ethernet cable. The data communicated includes:

- On Belt Analyser results

- On Belt Analyser status
- On Belt Analyser diagnostics.

2.5 Inputs and outputs

The inputs and outputs are shown on the Plant Interface Wiring Diagram.

2.5.1 Inputs from the plant

Digital inputs require voltage-free contact closures to be supplied by the plant. The LED's on the ADAM-5051D Digital Input module are reverse logic, i.e. LED on means input off and LED off means input on.

Digital Input from Plant	**Description**
DI0	Conveyor running
DI2	Tonnage-weighted reset A
DI3	Tonnage-weighted reset B
DI4	Tonnage-weighted reset C
DI5	Tonnage-weighted reset D
DI6	Stockpile / Product select 0
DI7	Stockpile / Product select 1
DI8	Stockpile / Product select 2
DI9	Stockpile / Product select 3
DI10	Force Analyse mode
DI11	Force Standardise mode
DI12	Force Source Off

Analogue inputs require a 4-20 mA signal calibrated for the Applicable plant output.

Analogue Input from Plant	**Description**
V0	Tonnes per hour
V1	Belt load
V2	Belt speed

2.5.2 Inputs from the analyser

Digital Input from Analyser	Description
DI14	Beam On Proximity Switch
DI15	Beam Off Proximity Switch

2.5.3 Outputs from the Analyser

The outputs are shown on the electrical installation drawings.

Digital Output to Plant	Description
N00	System OK
N01	Alarm 1
N02	Alarm 2

3 Normal operation

This chapter contains normal operating procedures for the On Belt Analyser. It contains the following sections:

◊ Modes of operation

◊ Pre-start checklist

◊ Starting the On Belt Analyser

◊ Shutting down the On Belt Analyser

3.1 Modes of operation

The On Belt Analyser has two operating modes:

- ANALYSE
- STANDARDISE.

Under normal operating conditions the On Belt Analyser is running continuously, switching automatically between ANALYSE and STANDARDISE modes depending on the belt loading.

Power should be continuously supplied to the On Belt Analyser which incorporates a backup UPS system.

The On Belt Analyser is turned off only for:

- maintenance
- emergency.

3.1.1 ANALYSE mode

ANALYSE mode is selected when all of the following conditions are met:

- the conveyor belt is running
- material is available at sufficient belt load
- no critical alarms exist.

The On Belt Analyser automatically switches to ANALYSE mode when material on the belt reaches a pre-defined belt load. The material is analysed and data is transmitted to the optional superSCAN PC or plant system. When the belt load drops below a minimum value, data is rejected to prevent inaccurate results.

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3.1.2 STATIC ANALYSE mode

This mode is used for collecting data either calibration samples or stopped belt samples during static calibration. When the belt has stopped and no material is on the belt, static analyse mode can be selected in the following ways:

- switching on Digital Input DI10
- writing a non-zero number to Modbus address 43501
- selecting static analyse mode from the optional superSCAN system

3.1.3 STANDARDISE mode

After commissioning is completed, standardisation is only performed during scheduled service visits. Regular standardisation is not required.

Scantech or its service agent must be notified if the conveyor belt is replaced so that the validity of the standardisation data can be checked.

Standardise mode is automatically selected when the belt has been running empty for 10 minutes. Typically, one standardisation period lasts for 2 hours.

If during the standardisation period the process is interrupted, the data is not collected and the process must be repeated.

Interruptions to a successful standardisation occur when:

- the belt stops
- material is detected on the belt.

3.2 Pre-start checklist

The On Belt Analyser operates continuously unless it is to be shut down for maintenance.

Before starting the system verify that:

- all connections and cabling are secure and undamaged
- the optional superSCAN PC or plant system is connected and operating.

3.3 Starting the On Belt Analyser

After installation and set up, all components are normally left turned on and are controlled by the Analyser computer .

The On Belt Analyser operates as long as it has power—there is no 'start' or 'stop' switch.

When starting from 'cold', the On Belt Analyser takes several hours to stabilise since the detectors have to reach their operating temperature. Power must be available continuously.

During this warm up period, analysis results are not calculated because the On Belt Analyser's detector gain and offset stabilisation systems are operating.

Optimum analysis results are not available until the detector enclosure has reached 20°C.

Normal operation requires no further operator action even after a power failure.

3.4 Shutting down the On Belt Analyser

To shut down the On Belt Analyser for an extended period, turn off the main circuit breaker labelled "CB1" by pushing its trip button. The UPS will supply power for approximately 10 minutes until the analyser goes through a routine shut down and the optional source drive safely stores the source. The UPS automatically switches itself off.

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4 Safety

The On Belt Analyser safety considerations relate to the neutron source. The On Belt Analyser Health and Safety Review explains its safety features in detail. The following sections briefly describe safety requirements and procedures.

◊ Shielding

◊ Neutron source

◊ Warning lights

◊ Source storage and insertion procedures

◊ Emergency procedure.

4.1 Shielding

The On Belt Analyser is basically a steel enclosure filled with cast neutron shielding (CNS). CNS is built into the top, bottom and sides of the enclosure and provides most of the shielding required. CNS is:

- a dense suspension of high density polyethylene beads cemented together with a mixture of borax and polyester resin
- waterproof, fireproof and non-corrosive.

CNS prevents the steel frame from becoming activated by neutrons. It contains high concentrations of hydrogen in the polyethylene, and boron in the borax. The hydrogen efficiently slows down the neutrons and the boron has a high cross section for thermal neutron capture. The shielding reduces radiation outside the enclosure to acceptable levels.

4.2 Neutron source

4.2.1 General description

The On Belt Analyser contains approximately 50 micrograms of Californium-
252 (Cf-252). During normal operations the neutron source is located directly underneath the conveyor belt in the centre of the analyser. During idler maintenance and, as required, the source can be removed and stored in the supplied source storage drum, outside of the On Belt Analyser. An optional automatic source drive can be fitted.

Normal operation

During normal operation the neutron source is located safe within the analyser, directly underneath the conveyor belt.

Source storage

When the source is removed, it is stored in the supplied source storage drum, which is filled with CNS.

Refer to the procedures on storing the neutron source in the supplied source storage drum and loading it into the On Belt Analyser.

4.3 Warning lights

The On Belt Analyser has conspicuous red and green warning lights mounted on the external surface of the control cabinet. They indicate the location of the Cf-252 source as follows:

- Red light indicates "BEAM ON" meaning that the source is inside the analyser and located directly under the conveyor belt.
- Green light indicates "BEAM OFF" meaning that the source is safely stored, either automatically stored towards the rear of the analyser if an automatic source drive is fitted, or manually stored in the supplied source storage drum.

Warning light switch

The warning lights are activated by proximity switches. If an automatic source drive is not fitted, the switches are located in the electronics cabinet, directly adjacent to the hole in which the source rod is inserted. By default the red warning light is illuminated, indicating that the source is either in or could be in the On Belt Analyser. When the source rod is removed, the source indicator plate is rotated to activate the BEAM OFF proximity switch. The green warning light will now be illuminated, indicating that the source is safely stored. This is a fail-safe mechanism, as the source rod cannot be inserted while the source indicator plate is in the BEAM OFF position.

If an automatic source drive is fitted, a proximity switch at the rear of the analyser is used to indicate whether the source is stored.

4.4 Source rod storage and insertion procedures

Important: The following procedure should only be performed by someone who is trained and licensed to handle sealed radioactive sources. If you are unsure of this procedure, please contact Scantech.

Refer to the On Belt Analyser Health and Safety Review for radiation dose rates at 5cm, 30cm and 100cm from the surface of the analyser and source storage drum.

Refer to Appendix A of this manual for a drawing of the source storage drum and source rod. The source rod must only be handled by the knurled end of the outer rod.

4.4.1 Storing the source rod

1. Position the source storage drum near the electronics cabinet.

2. Open the electronics cabinet door.

3. Remove the lid from the source storage drum, identify the central source storage tube and ensure it is not obstructed.

4. In the cabinet, remove the padlock for the source indicator plate.

5. Loosen the captive screw above the source indicator plate and then rotate the source indicator plate 90°.

6. Remove the first polyethylene sleeve to expose the knurled end of the source rod.

7. Hold the source rod by the knurled end and pull it outwards.

8. When completely out, quickly but carefully place the source rod into the central source storage tube of the source storage drum.

9. Lift the source rod about 15cm and use two spanners to unscrew the outer rod from the inner rod. Do not unscrew the inner rod from the source holder.

10. Drop the inner rod (joined to the source holder) into the deep hole.

11. Put the first polyethylene sleeve back onto the outer rod and drop it in the outer tube, so that it can not be lost.

12. Put the lid on the drum.

13. If the source is to be stored for an extended period, move the drum to a locked store. If the source is to be stored for a short period, keep it 5m away from personnel.

14. Rotate the source indicator plate to activate the BEAM OFF proximity switch and padlock it in this position.

15. Padlock the electronics cabinet doors and ensure that the green BEAM OFF light is illuminated.

4.4.2 Inserting the source rod into the On Belt Analyser

1. Position the source storage drum near the electronics cabinet.
2. Open the electronics cabinet door.
3. Remove the padlock for the source indicator plate.
4. Rotate the source indicator plate 90° to allow clear passage for the source rod. Note that when the BEAM OFF proximity switch is not activated, the red BEAM ON light on the cabinet door will illuminate.
5. Remove the lid from the drum.
6. Remove the outer rod from the outer tube.
7. Remove the first polyethylene sleeve to expose the knurled end of the outer rod.
8. Put the threaded end of the outer rod in the central source storage tube and turn to catch a couple threads of the inner rod.
9. Lift the source rod until the threaded join is in view, and then tighten the connection between the outer rod and inner rod thread using the two spanners.
10. Hold the source rod by the knurled tip and quickly but carefully move it into the On Belt Analyser source hole, pushing it as far as it goes.
11. Replace the first polyethylene sleeve on the source rod.
12. Rotate the source indicator plate to activate the BEAM ON proximity switch and padlock it in this position.
13. Padlock the electronics cabinet doors and ensure that the red BEAM ON light is illuminated.

4.5 Emergency procedure

If an accident occurs in which:

- structural damage to the On Belt Analyser is possible
- exposure of the radioactive source is

suspected. Then:

- Turn off mains power.
- Store the source, if possible.
- Rope off area of ten metres minimum around the On Belt Analyser.
- Deny ALL access to the On Belt Analyser and the roped off area.
- Call Scantech immediately — the phone number is on the back of the title page of this manual.
- Notify any emergency personnel of the source presence and possible causing damage.
- Notify the appropriate licensing authority.

CAUTION

Scantech authorisation is required to repair or handle a damaged On Belt Analyser.

4.6 Recovery from power failures

The On Belt Analyser is set up to recover automatically from power failures and no operator actions are required.

5 Maintenance procedures

This chapter contains instructions for normal maintenance. It contains the following sections:

◊ Maintenance schedule

◊ Wipe test

◊ Source rod operation inspection

◊ Static Calibration maintenance

5.1 Maintenance schedule

The following table describes the recommended preventive maintenance schedule:

Time period	Action
Weekly	Inspect the On Belt Analyser for damage (eg high belt loads causing material to impact the analyser frame). Inspect the electronics cabinet. Verify that electronics cabinet door is closed and padlock is in place. Inspect heat sinks on both air conditioners. Clean with compressed air if dust occupies more than half the volume around heat sinks. Inspect the tunnel for: 1. dust build up - clean with compressed air if necessary. 2. evidence of contact between belt and tunnel – if so check adjacent idlers and notify Scantech.
Three-monthly	Run calibration samples to verify static calibration.
Six-monthly	*(normally performed by Scantech service engineers)* Verify satisfactory condition of all components as per service visit checklist.
Two-yearly	*(normally performed by Scantech service engineers)* Replenish Cf-252 neutron source as required. Perform a wipe test if required.

☞ The frequency of wipe tests may vary in response to local legislation.

5.2 Wipe test

Important: The following procedure should only be performed by someone who is trained and licensed to handle sealed radioactive sources. If you are unsure of this procedure, please contact Scantech.

Refer to the On Belt Analyser Health and Safety Review for radiation dose rates at 5cm, 30cm and 100cm from the surface of the analyser and source storage drum.

1. Remove the source rod as per the "Storing the source rod" procedure.
2. Attach a cotton ball to the end of a 1.5m length of 5mm diameter dowel stick.
3. Dip the cotton ball in methylated spirits.
4. Insert the dowel stick (cotton ball first) far into the analyser's source rod hole, rotating it so that the cotton ball contacts the inner surface of the hole.
5. Withdraw the dowel stick and remove the cotton ball.
6. Place the cotton ball into a clean sealable plastic bag, labelled with the day's date and description of wipe, for example, "On Belt Analyser source rod hole".
7. Put the source rod back into the analyser as per the "Inserting the source rod into the On Belt Analyser" procedure.
8. Send the cotton ball off for a radiation leak test analysis.
9. If there is evidence of source leakage, contact Scantech.

5.3 Source rod operation inspection

The condition of the source rod should be inspected each time it's stored for maintenance. Before fully extracting the source rod from the On Belt Analyser, ensure that it moves freely within the source hole by moving it back and forth 30cm. If it does not move freely, then it may be bent, in which case Scantech should be contacted.

5.4 Static Calibration maintenance

This is the procedure for analysing the calibration samples.

1. Ensure no material on belt and belt is isolated.
2. Force the On Belt Analyser into Static Analyse mode.
3. Place the empty calibration container onto a section of conveyor adjacent to the analyser.
4. Place sealed bags from one calibration sample into the empty calibration container and move it into the analyser tunnel using a winch or by inching the conveyor (if belt has VF drive with local Start/Stop switch).
5. Analyse the calibration sample for 1.5 hours.
6. Record the sample number and corresponding start and stop date/times.
7. Remove the calibration container from the analyser tunnel using a winch or by inching the conveyor if possible.
8. Repeat steps 3 – 7 until all calibration samples have been analysed.
9. Contact Scantech for assistance with calibration verification.

6 Fault finding

This chapter outlines fault finding information for the On Belt Analyser and its components. It contains the following sections:

◊ Initial checks

◊ UPS faults

◊ Air conditioner faults

◊ Analyser computer faults

6.1 Initial checks

Before you proceed to work from the specific fault finding charts, complete the checklist below.

Contact the Scantech service engineer if any initial check fails.

Table 1: Initial fault finding checklist

(✓)	FAULT	COMMENT
☐	Is the mains power circuit breaker 'ON'?	If the mains circuit breaker will not stay 'ON', one or more of the following conditions may apply: • earth leakage • short circuit • overload condition.
☐	Are all component circuit breakers 'ON'?	If the circuit breakers will not stay 'ON', one or more of the following conditions may apply: • short circuit • overload.
☐	Is UPS 'ON'?	A green LED next to the "~" symbol indicates normal operation. Refer to the UPS Faults section below for other LED indications.

☐	Is the source rod inside the analyser with the red BEAM ON light illuminated?	Verify: • The source indicator plate is in contact with the BEAM ON proximity switch, illuminating the red LED behind it. • BEAM ON and BEAM OFF proximity switches activate Digital Inputs DI14 and DI15 respectively (Note: ADAM module uses reverse logic so that LED off means

Table 1: Initial fault finding checklist

(✓)	FAULT	COMMENT
		input is on).
☐	Is there material on the belt?	If material is visible on a moving belt, verify the following plant inputs: • Conveyor running (DI 0) • Tonnes per hour (analogue input).
☐	Is the analyser in ANALYSE mode?	Verify using the superSCAN or plant system

6.2 UPS faults

Table 2: UPS fault finding checklist

Fault	Cause	Solution
UPS cannot turn on and has no alarm.	The UPS Circuit breaker has tripped or UPS main switch is off.	Turn the UPS circuit breaker on or turn the UPS on using the button on its front panel.
UPS beeps when incoming line is thought to be normal.	No incoming line or very low or very high line voltage.	Verify condition of wall socket. Test the input line voltage.
	UPS input power cable not plugged in.	Plug in input power cable.
	Rear panel circuit breaker is tripped.	Reset the circuit breaker.

Refer to the following Troubleshooting table from the Powerware 5115A USB User's Guide (used with permission).

Indicator Legend

- Lit
- Flashing

Troubleshooting Guide

Alarm or Condition	Possible Cause	Action
The indicator is not on, the UPS does not start	The power cord is not connected correctly.	Check the power cord connections.
	The wall outlet is faulty.	Have a qualified electrician test and repair the outlet.
The UPS operates in Battery mode only, even though normal utility power is present	The input overcurrent protector is open	Save your work and turn off your equipment. Turn off the UPS. Reduce the load, then press the input overcurrent protector on the UPS rear panel.
UPS does not provide the expected backup time	The batteries may be fully discharged because of: • long-term storage • frequent power outages • end of battery life	Plug the UPS into a power outlet for 24 hours to charge the battery. Press the button; if the alarm beeps, see "Replacing the Batteries" on page 16 to replace the battery. During extended power outages, turn off the UPS after saving your work and shutting down your computer to conserve battery charge.
	Normal operation.	None. The UPS is operating in Normal mode and automatically provides consistent voltage with the Buck and Boost feature.
1 beep every 4 seconds	Utility power failure.	The UPS is powering your equipment with its internal battery. If this is an extended power outage, save your work and turn off your equipment to conserve battery power.
1 beep every 2 seconds	The battery is running low.	2 minutes or less of battery power remains (depending on load configuration and battery charge). Prepare for a shutdown. Save your work and turn off your equipment. The alarm cannot be silenced.
1 beep every 2 seconds	The UPS is running on battery power because the input voltage is too high or too low.	Correct the input voltage, if possible. The UPS continues to operate on battery until the condition is corrected or the battery is completely discharged. If the condition persists, the input voltage in your area may differ from the UPS nominal.
1 beep per second	Power requirements exceed UPS capacity (overload is greater than 120%) or the load is defective.	The UPS will automatically shut down in 3 minutes. Save your work immediately and turn off your equipment. Turn off the UPS. Remove some of the equipment from your UPS. You may need to obtain a larger capacity UPS.
1 beep per second	The UPS is on battery and the power requirements exceed UPS capacity (overload is greater than 120%) or the load is defective	Shutdown is imminent (30 seconds). Save your work and turn off your equipment. Turn off the UPS. Remove some of the equipment from the UPS. You may need to obtain a larger capacity UPS.
Continuous beep	Battery test failed.	Check the battery connections and be sure the battery is fully charged. If the indicator still flashes, see "UPS Maintenance" on page 15 to replace the battery. Call your service representative if the problem persists.
Continuous beep	UPS internal temperature is too high	Shutdown is imminent. Save your work and turn off your equipment. Turn off the UPS. Clear vents and remove any heat sources. Wait at least 5 minutes and restart the UPS. If the condition persists, contact your service representative.
Continuous beep	UPS fan fault (750-1400VA models only)	Save your work and turn off your equipment. Turn off the UPS. Contact your service representative.
3 beeps every 10 seconds	Failed attempt to start the UPS on battery.	Plug the UPS into a power outlet for 24 hours to charge the battery. After charging the battery, press and hold the button for 3 seconds. Then check the indicator. If the still flashes, see "UPS Maintenance" on page 15 to replace the battery.
Continuous beep	The output wave is abnormal while the UPS is on battery.	Shutdown is imminent. Save your work and turn off your equipment. Turn off the UPS. Contact your service representative.
Continuous beep	The output voltage is below or above the limit while the UPS is on battery.	Save your work and turn off your equipment. Turn off the UPS. Contact your service representative.

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6.3 Air conditioner faults

If a fault is suspected in either air conditioner, perform the following:

Table 3: Air conditioner fault finding checklist

(✓)	ACTION
	Verify that the circuit breaker is ON.
☐	Verify that the digital controller on the air conditioner displays the correct temperature: Detector enclosure 20°C +/- 0.5°C Electronics cabinet 30°C +/- 0.5°C
☐	Verify that the heat sinks are clean.
☐	If dust occupies more than half the volume around the heat sinks, turn the air conditioner off at the circuit breaker and blow dust out with compressed air.
☐	Verify that the ambient side fans switch on and off every few seconds.
☐	If necessary replace the faulty air conditioner. The spare air conditioner setpoint will be 20 °C. To change the setpoint to 30 °C for the electronics cabinet: • Press the up and down arrow buttons together for 3 seconds • Up arrow to SP.LK (Setpoint lock – currently ON) • Press the * and up arrow buttons together to select OFF • Press the up and down arrow buttons together for 3 seconds • Hold the * and up arrows together until the setpoint is 30.0 • Press the up and down arrow buttons together for 3 seconds • Up arrow to SP.LK (Setpoint lock – currently OFF) • Press the * and up arrow buttons together to select ON • Press the up and down arrow buttons together for 3 seconds

6.4 Analyser computer faults

If a fault is suspected with the analyser computer, perform the following:

Table 4: Analyser computer fault finding checklist

(✓)	ACTION
☐	Verify that: • the circuit breaker is ON. If not, switch it ON. • the green LED on the power connector into the back of the PC is ON. If not, check cable connections into the transformer. • the UPS is ON. • the power light on the front of the PC is ON.
☐	If Modbus output or local PC Anywhere access is not working, reboot the Analyser computer using the Reset button on the front of the PC. The PC should restart automatically within approx 2 minutes.
☐	If PC Anywhere modem access is not working, reboot the Analyser computer using the Reset button on the front of the PC.
☐	If the Analyser computer needs replacing, copy the C:\CsParamServer.dat file from the failed computer to a USB flash drive, transfer the dongle to the replacement computer and copy the file to its C:\ folder. This file contains all parameters and accumulator data. Overwrite the existing CsParamServer.dat file.

6.5 Spare parts (standard listing)

Scantech part number	Qty	Description
1610-00-0035	1	ANALYSER PC
3200-00-0034	1	POWER SUPPLY, 24Vdc, 50W
3200-00-0033	1	POWER SUPPLY, 12Vdc, 50W
2670-00-0006	1	AIR CONDITIONER, PELTIER SOLID STATE
1612-00-0022	1	BELKIN USB HUB
1612-00-0015	1	SURGE SUPPRESSION, ETHERNET
4210-00-0005	1	SURGE SUPPRESSION, MAINS
4210-00-0006	1	SURGE SUPPRESSION, PHONE
3660-00-0004	2	RELAY, 14 PIN, 4 POLE, 24VDC

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APPENDIX II

On Belt Analyser-5

Health & Safety Review

Version 1.6

February 2006

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1. Foreword

The On Belt Analyser-5 is intended for the analysis of bulk materials directly on a conveyor belt. The analyser may be installed on existing plant conveyor belts with minimal modification to the existing plant. A major advantage of on-belt analysis is that all the process material is analysed. Other methods, which analyse a sub sample of the process, are subject to the errors in the sampling method used.

The On Belt Analyser-5 is specifically designed for conveyor belts with widths between 600mm and 1400mm.

The name On Belt Analyser-5 is an abbreviation for the full model number of the analyser.

2. General Description of the On Belt Analyser-5

The On Belt Analyser is manufactured by Scantech for the continuous on-belt analysis of the elemental content of bulk materials.

The On Belt Analyser-5 uses the technique of Prompt Gamma Neutron Activation Analysis (PGNAA). A belt carrying the material to be analysed passes through the tunnel of the analyser. An isotope neutron source below the belt is used to excite characteristic gamma ray emissions from the elements in the material. A gamma ray detector array above the belt is used to analyse the gamma rays emitted by the material.

The On Belt Analyser-5 frame provides structural strength and protection for the internal components and shielding. The frame is filled with Cast Neutron Shielding (CNS) forming a physically strong and fire-resistant radiation shield. The CNS completely surrounds the conveyor belt except for the tunnel entry and exit points.

During normal operation, the neutron source is located directly underneath the belt. During conveyor maintenance and whenever required, the source may be removed and stored in the supplied source storage drum.

The On Belt Analyser-5 has a C-shaped construction and a side shield, which is inserted to complete the tunnel when the belt is in position. The belt does not contact the analyser and the return belt travels underneath the analyser. The belt may be any normal, commercial conveyor belt, up to a width of 1400mm, which can be replaced or repaired as required.

The detectors and multi channel analyser electronics are located within the air conditioned, temperature controlled detector enclosure above the conveyor belt. The analyser computer and other electronics modules are located within the air-conditioned, temperature controlled electronics cabinet, which has a sealed and locked door.

3. Radioisotope used

Californium-252

Initially, a single Californium-252 source with a maximum activity of nominally
50 micrograms will be installed in the On Belt Analyser-5. Because of the short half-life of this isotope (2.65 years), the sources must be "topped up" by adding a new source capsule approximately every two and a half years.

Two suppliers of sources may be used; AEA Technology or Frontier. The details of the sources are:

AEA Technology Source

Type CVN.CY2, 50 micrograms (0.99 GBq or 26.8 mCi), Amersham X1 capsule, double encapsulated. This capsule has ISO Classification[1] C66545, which is in excess of the minimum requirement specified by ANSI N542 1977. The source has special form certification, certificate no. GB/007/S-85.

Frontier Source

Type 10S, 50 micrograms (0.99 GBq or 26.8 mCi), double encapsulated. This capsule has ISO Classification[2] 97E66543, which is in excess of the minimum requirement specified by ANSI N542 1977. The source has special form certification, certificate no. USA/0367/S.

Typical test certificates and Special Form Certificates for these sources are included in Appendices A and B.

[1] Refers to BS5288:1976 which is in agreement with ISO 2919
[2] Refers to ISO 2919

4. Design Considerations For Radiation Safety

The analyser is a steel enclosure filled with cast neutron shielding (CNS). There are polyethylene tunnel extensions at both tunnel openings to reduce the radiation levels. A conveyor belt allows the material stream to pass through the analyser. The source housing and detector housings are embedded in the shielding, with sufficient shielding being provided so that the dose rates on the surface of the analyser are maintained at an acceptable level.

The CNS is a dense suspension of high-density polyethylene beads cemented together with a mixture of borax and polyester resin. This material provides most of the shielding required. This material is effective at slowing down and absorbing neutrons. It is also waterproof, non-corrosive and intrinsically fire resistant.

In the event of a fire adjacent to the external surfaces the CNS will retain its shape inside the steel exterior shell. Since the CNS will not burn, the instrument is thus effectively protected against fire from the exterior. This has been demonstrated by subjecting a test sample, containing CNS, to a furnace test (see Appendix C).

The source rod is located behind a lockable source indicator plate, which is located inside the locked electronics cabinet.

During normal operation, the source rod is inside the On Belt Analyser-5 and the source indicator plate is rotated to the BEAM ON position, activating the proximity switch for the red BEAM ON light on the cabinet door. The source rod can not be removed while the source indicator plate is padlocked in the BEAM ON position. Even when the padlock is removed, the source indicator plate can not be rotated to the BEAM OFF position while the source rod is in the On Belt Analyser-5.

When the source rod is removed and stored in the source storage drum, the source indicator plate is rotated and locked in the BEAM OFF position. This activates the proximity switch for the green BEAM OFF light on the cabinet door. The source rod cannot be inserted into the On Belt Analyser-5 when the source indicator plate is in this position.

This fail-safe source status mechanism means that there can be no mistake as to whether the source rod is in the On Belt Analyser-5 or not. Even in the event of a power outage, in which the indicator lights are both off, the source indicator plate will show the true source status.

The source storage drum has a 270mm thickness of CNS around a central tube where the source rod is stowed, providing sufficient shielding.

5. Description of the Neutron Source Rod

The source rod is illustrated in Appendix D.

The source rod is made entirely from stainless steel and is comprised of three sections. The first is the “source holder”, which is 68mm long and holds up to three 20mm long source capsules. The second is the “inner rod”, which is 358mm long and has a cap at one end which screws onto the source holder to enclose the source capsules. The third is the “outer rod”, which is 680mm long and screws onto the inner rod. The source rod should only be handled by the knurled end of the outer rod to maximise distance between the source and the person holding it.

The source holder is initially fitted with one 50 microgram Californium source and two spacers. However additional sources should be installed to maintain total activity as the original source decays.

In the unlikely event that the source rod becomes disconnected at one of its threads, or breaks, the source holder can be carefully removed as follows. A small lockable cover on rear side of the analyser can be removed so that a length of straight rigid wire can be slowly poked into the hole to push the source holder towards the electronics cabinet. As soon as it becomes visible from the electronics cabinet, it should be pulled out and placed into the nearby source storage drum. The source rod can not be pushed out unless the source indication plate is unlocked and partially turned through 90 degrees towards the BEAM OFF position. Note that the source rod cannot be extracted towards the rear side of the analyser.

6. The Neutron Source Housing

Normal Operation

During normal operation the neutron source is positioned underneath the belt. The source is housed in the neutron source holder described in section 6. The holder is located in a high-density metal block. This block is surrounded by a series of neutron reflectors and neutron moderators. All of this material is surrounded by cast neutron shielding (CNS).

Source Storage Drum

The source storage drum is shown in Appendix D.

During maintenance and at any other required time, the source rod may be removed from the analyser and stored in the supplied source storage drum.

Refer to the Operation and Maintenance manual for a procedure on removing and storing the source rod in the source storage drum. This should only be attempted by a Scantech engineer or an appropriately trained person with a radiation licence.

7. Radiation Dose Rates

An On Belt Analyser-5 radiation survey was conducted from 17th March to 24th March 2005. Instruments used were:

A. Neutron Meter: Model 12-4 neutron dose meter
S/N 192476
Manufactured by Ludlum Measurements Inc.
Sweetwater Texas USA
Calibrated by Ludlum to ANSI/NCSL Z540-1-1994 and ANSI N323-1978 standard on 27th February 2005

B. Gamma Meter: Model 9 ionisation chamber gamma dose meter
S/N 183526
Manufactured by Ludlum Measurements Inc.
Sweetwater Texas USA
Calibrated by Ludlum to ANSI/NCSL Z540-1-1994 and ANSI N323-1978 standard on 27th February 2005

At the time of the On Belt Analyser-5 survey, the Californium sources that were used had a total activity of 1.02 GBq (51.7 micrograms).

At the time of the Source Storage drum survey in May 2002, different Californium sources were used and had a total activity of 1.4 GBq (71.4 micrograms).

All measured dose rates have been scaled for a 50ug Californium source.

Dose Rate Measurements External to the Analyser

Dose rates were measured on all accessible surfaces of the analyser.

Gamma measurements were made at distances of 5cm, 30cm and 100cm from the surface of the analyser.

The neutron dosemeter consists of a neutron counter tube inside a polyethylene sphere 230 mm in diameter. The 5cm neutron measurements were made with the sphere in contact the surface of the analyser. Measurements were also made with the centre of the sphere at 30cm and 100cm from the surface of the analyser.

The following measurements were taken:

1. On Belt Analyser-5, Belt empty.

2. On Belt Analyser-5, Belt loaded with a typical 200mm depth of crushed material.

3. Source storage drum

   This is the condition of the source storage drum when source rod is stored in the central tube of the drum. The outer rod is unscrewed and stored inside the analyser's electronics cabinet.

NOTE: The reference points shown in Figures 6 to 13 indicate the points where the measurements are made at the surface of the analyser. Measurements are made at 5cm, 30cm and 100cm adjacent to and on a level plane from that reference point.

BEAM ON Empty belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
A1	2	6	8	2	5	7	1	4	4
A2	4	6	9	2	4	6	2	3	5
A3	2	4	6	2	4	6	2	4	6
H1	9	23	32	8	11	19	2	3	5
H2	7	9	16	5	9	14	2	4	6
H3	5	8	13	4	7	11	1	3	4
H4	10	11	21	7	7	14	3	4	7
H5	6	4	10	5	6	11	2	4	6
H6	5	4	9	4	5	9	2	3	5
H7	7	9	16	5	7	12	4	5	9
H8	7	8	15	5	5	10	4	4	8
H9	5	6	11	4	4	8	3	4	7

BEAM ON Loaded belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
A1	3	3	5	2	2	4	1	2	3
A2	4	2	6	4	3	6	1	2	3
A3	3	2	5	2	2	4	1	2	3
H1	7	8	15	3	5	8	1	3	4
H2	3	4	7	2	5	7	1	3	4
H3	3	3	6	2	4	6	1	2	3
H4	10	8	18	4	6	10	1	4	5
H5	5	2	7	3	5	8	1	4	5
H6	4	2	6	3	4	7	1	2	3
H7	8	8	16	3	4	7	1	2	3
H8	6	5	11	3	3	6	1	2	3
H9	4	3	7	2	3	5	1	2	3

BEAM ON Empty belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
B4	6	7	13	7	9	16	5	8	13
B8	4	11	15	6	4	10	5	4	9
B12	4	8	12	7	8	15	5	6	11
X	16	107	123	15	72	87	10	35	45

BEAM ON Loaded belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
B4	5	5	10	5	7	12	2	15	17
B8	6	7	13	4	8	12	2	18	20
B12	3	6	9	2	7	9	1	8	9
X	10	23	33	11	16	27	2	5	7

BEAM ON Empty belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
C1	5	7	12	7	9	16	5	8	13
C5	4	10	14	6	4	10	5	4	9
C9	4	7	11	7	8	15	5	6	11
Y	15	103	118	14	73	87	11	33	44

BEAM ON Loaded belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
C1	5	6	11	7	9	16	5	7	12
C5	4	10	14	6	4	10	5	5	10
C9	4	7	11	7	8	15	5	6	11
Y	11	21	32	10	18	28	2	5	7

BEAM ON Empty belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
D1	2	7	10	3	7	9	2	4	6
D2	3	8	10	3	9	11	2	3	5
D3	2	8	10	3	7	9	2	6	7
D4	5	9	14	4	9	12	2	4	6
D5	7	13	19	4	8	12	2	5	7
D6	5	10	14	3	6	9	2	5	7
D7	2	4	5	2	4	5	2	4	5
D8	2	3	5	3	4	7	2	3	4
D9	2	3	4	2	4	6	2	3	5

BEAM ON Loaded belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
D1	6	5	10	6	3	9	2	3	5
D2	7	6	13	7	4	11	3	3	6
D3	6	6	12	6	4	10	2	3	5
D4	10	7	17	7	5	12	3	2	5
D5	12	9	21	8	4	11	4	3	7
D6	11	10	21	8	4	12	3	2	5
D7	6	3	9	6	2	8	3	1	4
D8	7	3	10	6	2	8	3	1	4
D9	5	4	9	5	3	8	2	2	4

BEAM ON Empty belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
E1	9	66	75	8	82	90	3	35	38
E2	20	99	119	10	92	102	5	31	36
E3	9	65	74	8	84	92	4	37	40
E4	8	45	53	7	46	53	4	24	28
E5	8	66	74	5	45	50	4	14	18
E6	8	44	52	8	48	56	4	22	26
E7	8	65	73	7	86	93	4	38	41
E8	21	98	119	10	90	100	5	29	34
E9	9	66	75	9	85	94	3	39	42
E10	2	6	8	1	3	4	2	6	8
E11	2	7	9	2	6	8	2	8	10
E12	2	7	9	1	3	4	2	7	9
G1	4	7	11	2	7	9	2	11	13
G2	4	12	16	3	8	11	2	6	8
G3	4	9	13	3	6	9	1	4	5
G4	11	20	31	5	20	25	2	22	24
G5	10	25	35	7	15	22	3	12	15
G6	5	9	14	4	12	16	1	9	10
G7	5	7	12	2	8	10	2	10	12
G8	5	11	16	3	10	13	1	6	7
G9	3	9	12	3	5	8	2	4	6

BEAM ON Loaded belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
E1	11	23	34	8	24	32	3	10	13
E2	12	26	38	10	28	38	3	10	13
E3	11	22	33	8	24	32	3	9	12
E4	11	13	23	8	20	28	3	10	13
E5	7	21	28	6	16	22	3	8	11
E6	10	12	22	8	22	30	3	9	12
E7	12	22	34	8	23	31	3	9	11
E8	13	27	40	9	27	36	3	9	11
E9	11	23	34	8	24	32	3	9	12
E10	2	2	4	2	1	3	2	0	2
E11	2	2	4	2	1	2	2	0	2
E12	2	2	4	2	1	3	2	0	2
G1	5	3	8	3	4	7	1	2	3
G2	3	2	5	3	3	6	3	3	6
G3	3	2	5	2	2	4	2	3	5
G4	9	6	15	3	6	9	2	5	7
G5	7	4	11	5	5	10	2	3	5
G6	3	3	6	3	5	8	2	3	5
G7	5	2	7	3	3	6	1	1	2
G8	3	1	4	2	3	5	2	3	5
G9	2	2	4	2	3	5	2	2	4

BEAM ON Empty belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
F1	3	9	12	5	9	14	5	11	16
F2	7	9	16	7	14	21	4	10	14
F3	4	9	13	4	8	12	4	11	15
F4	17	34	51	14	28	42	6	12	18
F5	36	76	112	22	42	64	6	13	19
F6	18	35	53	13	26	39	5	12	17
F7	3	8	11	5	8	13	5	12	17
F8	8	9	17	6	14	20	4	9	13
F9	4	8	12	5	8	13	4	12	16

BEAM ON Loaded belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
F1	3	8	11	6	8	14	5	12	17
F2	8	10	18	7	12	19	3	10	13
F3	4	10	14	4	7	11	4	10	14
F4	16	30	46	14	25	39	6	10	16
F5	32	80	112	20	45	65	7	10	17
F6	16	36	52	15	25	40	6	12	18
F7	3	7	10	5	6	11	4	10	14
F8	7	10	17	6	14	20	4	8	12
F9	4	8	12	6	8	14	3	12	15

Source storage drum radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			**30cm**			**100cm**		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
A	33	25	59	19	14	33	9	10	19
B	315	322	637	81	154	235	25	33	58
C	280	280	560	93	175	268	24	36	60
D	280	308	588	87	182	269	23	39	62
E	280	210	490	91	126	217	20	39	59
F	280	252	532	98	168	266	25	32	57

8. Compliance with the Annex III tests the NHMRC Code of Practice for the Safe Use of Radiation Gauges

Radiation gauges such as the On Belt Analyser-5 present difficulties in interpretation of the requirements of the NHMRC Code of Practice. There is no single component within the analyser that performs all the requirements of a source housing as defined by the code. Because of the size and weight of the analyser it is generally not possible to carry out testing on a complete analyser.

During normal operation, the source is located under the conveyor belt. The physics of operation of the gauge limits the materials that can be used near the source. In this region the source is contained in a solid structure of graphite and gamma ray shielding.

The free drop test

The On Belt Analyser-5 is a large device of dimensions 2240mm long by 1000 mm wide by 1700mm high with a weight of approx 2000 kg. The On Belt Analyser-5 is installed as part of a material handling plant and it is difficult to imagine the circumstances in which the gauge could fall.

The On Belt Analyser-5 is a strong steel box which would retain the source in the event of extreme damage to the internal components analyser.

Exemption from conducting a drop test is requested since it is not possible to identify a component of the analyser which would provide useful information if dropped.

The thermal test

The primary shielding for both neutrons and gamma rays is the cast neutron shielding (CNS) which is built into the body of the analyser. A test sample containing this shielding has been subjected to a fire test and showed only minor degradation. Refer to Appendix C.

The high thermal mass and fire resistant properties of the CNS provides protection against fire for the components within the analyser.

In assessing the requirements of the thermal test, the location of the source housing within the analyser must be considered. The On Belt Analyser-5 frame contains a large quantity of CNS. This is protected on outside surfaces by a continuous skin of 3 mm thick steel. The CNS provides a large thermal mass which must be heated before the source itself is exposed to high temperatures. The CNS has also been demonstrated to be intrinsically fire resistant.

The above argument demonstrates that it is unlikely that fire will cause excessive damage to the neutron source housing. However the consequences of extreme fire damage to the source housing should still be considered. If the graphite and CNS components are all completely destroyed, the neutron source will still be held captive on the end of the stainless steel source rod. Therefore the source will not move. The CNS, which provides the bulk of the neutron shielding, will not burn and this will remain within the shielding walls of the analyser. Adequate neutron shielding will remain in place to significantly reduce neutron dose rates external to the analyser.

Corrosion and vibration test

It would be difficult to conduct a vibration test on the complete analyser. Individual components of the analyser could be shown to pass a vibration test but it would be difficult to extrapolate these tests to the complete analyser.

When installed, the large mass of the On Belt Analyser-5 will protect the internal components from excessive levels of vibration. The analyser is designed to be shipped to site fully assembled (except for the source) which requires resistance to significant levels of vibration.

Most of the internal components of the On Belt Analyser-5 are constructed from materials which are resistant to corrosion, such as stainless steel and aluminium. The bulk of the analyser is Cast Neutron Shielding (CNS) which is waterproof and will not corrode. The external steel case has a corrosion resistant coating. However if rusting occurred this would be very apparent before any radiation hazard existed.

9. Radiation Signs and Warning Plates

Radiation Warning Signs

These signs are 300 x 220 mm and have black writing on a yellow background (figure 1). Two of these are used. The signs are placed so that it is not possible to approach the analyser without seeing one of the signs.

Radioactive Source Identification Plate

This plate shows details of the sources. The plate is made from stainless steel. The writing is black on a yellow background and etched into the plate so that it would be visible after a fire. The details of the source are stamped onto the plate (figure 2).

The plate is shown actual size. Each plate has space for two sources. One or more plates is supplied depending on the number of sources installed.

The warning plate(s) are riveted to the front of the On Belt Analyser-5 frame.

10. Discussion of the Results of a Thermal Test on a Sample of Cast Neutron Shielding

The argument for the On Belt Analyser-5 remaining safe after a fire is based on the ability of the cast neutron shielding (CNS) to resist a fire. This has recently been tested by exposing a sample of CNS to a thermal test of 800 degrees centigrade for 30 minutes.

Appendix C. contains a description of the test sample and photographs showing the test and the dismantling of the sample after the test. A statement by an independent witness is also included.

The sample of shielding was constructed in a way which simulated the structure of the On Belt Analyser-5. The CNS was cast into a steel box using a similar technique as is used with the analyser.

The thickness of CNS used in the On Belt Analyser-5 is typically 300 to 400mm. The furnace test damaged the CNS to a depth of less than 20 mm. This loss of shielding will not result in a significant rise of radiation levels external to the analyser.

Unmelted polyethylene beads were found less than 20 mm from the surface of the CNS. Since the source rod is surrounded by a thickness of CNS greater than 20mm it can be assumed that they will not be exposed to a temperature greater than the melting point of polyethylene (133 degrees C). The melting point of stainless steel used in the source rod is 1450 degrees C.

The design of the On Belt Analyser-5 and the quantity of CNS used therefore provides a significant degree of thermal protection for critical components within the analyser. However if an extreme situation arose which resulted in complete destruction of all shielding within the analyser the steel frame would remain intact and the sources in their source holder would remain captive in the lower section of the frame.

Appendix A Details of AEA Technology Californium-252 Source

U.S. Department of Transportation
Research and Special Programs Administration

400 Seventh St., S.W.
Washington, D.C. 20590

IAEA CERTIFICATE OF COMPETENT AUTHORITY
SPECIAL FORM RADIOACTIVE MATERIALS
CERTIFICATE NUMBER USA/0632/S, REVISION 2

This certifies that the sources described have been demonstrated to meet the regulatory requirements for special form radioactive material as prescribed in the regulations of the International Atomic Energy Agency[1] and the United States of America[2] for the transport of radioactive materials.

1. Source Identification - AEA Technology QSA, Inc. Model Nos. AX1, X.1, and X.1/2.

2. Source Description - All models are a cylindrical double encapsulation made of stainless steel and tungsten inert gas or laser seal welded. Approximate outer dimensions of all models are 7.9 mm (0.31 in.) in diameter and 10.15 mm (0.4 in.) in length. Construction shall be in accordance with attached AEA Technology QSA, Inc. Drawing No. RBA10880, Rev. D.

3. Radioactive Contents - No more than either 3.7 GBq (100 mCi) Americium-241 or 13 GBq (351 mCi) Californium-252. The Am-241 is in oxide form and mixed with Beryllium powder and pressed into a solid pellet. The Cf-252 is in the form of a metal wire or an oxide solid ceramic.

4. Quality Assurance - Records of Quality Assurance activities required by Paragraph 310 of the IAEA regulations[1] shall be maintained and made available to the authorized officials for at least three years after the last shipment authorized by this certificate. Consignors and consignees in the United States exporting or importing shipments under this certificate shall satisfy the requirements of Subpart H of 10 CFR 71.

5. Expiration Date - This certificate expires June 15, 2008. On December 31, 2003, this certificate supersedes, in its entirety, all previously issued revisions of USA/0632/S.

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1 "Regulations for the Safe Transport of Radioactive Material, 1996 Edition (Revised), No. TS-R-1 (ST-1, Revised)," published by the International Atomic Energy Agency (IAEA), Vienna, Austria.

2 Title 49, Code of Federal Regulations, Parts 100 - 199, United States of America.

(- 2 -)

CERTIFICATE USA/0632/S, REVISION 2

This certificate is issued in accordance with paragraph 804 of the IAEA Regulations and Section 173.476 of Title 49 of the Code of Federal Regulations, in response to the petition and information dated October 10, 2003 and December 1, 2003 submitted by AEA Technology QSA, Inc., Burlington, MA, and in consideration of other information on file in this Office.

Certified by:

Robert A. McGuire
Associate Administrator for
Hazardous Materials Safety

DEC - 8 2003
(DATE)

Revision 2 - Issued to reflect construction dimensions and add optional spacers and/or ceramic fiber packing.

Appendix B Details of Frontier Californium-252 Source

U.S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration

400 Seventh Street, S.W.
Washington, D.C. 20590

IAEA CERTIFICATE OF COMPETENT AUTHORITY
SPECIAL FORM RADIOACTIVE MATERIALS
CERTIFICATE USA/0367/S-96, REVISION 7

This certifies that the sources described have been demonstrated to meet the regulatory requirements for special form radioactive material as prescribed in the regulations of the International Atomic Energy Agency[1] and the United States of America[2] for the transport of radioactive material.

1. Source Identification - Frontier Technology Corporation Model 10 Series and Model 100 Series.

2. Source Description - The Model 10 Series source capsules are cylindrical single encapsulations made of Type 304L stainless steel or Zircalloy-2 and tungsten inert gas fusion welded. Approximate outer dimensions are 5.5 mm (0.22 in.) in diameter and either 11.9 mm (0.47 in.) or 24.6 mm (0.97 in.) in length. The Model 100 Series source capsules are cylindrical double encapsulations made of Type 304L stainless steel or Zircalloy-2 and tungsten inert gas fusion welded. The inner capsule is a Model 10 Series source capsule. Approximate outer dimensions are either 7.7 mm (0.3 in.) or 9.4 mm (0.37 in.) in diameter and either 19.6 mm (0.77 in.) or 32.5 mm (1.28 in.) in length. The overall length may be extended by attachment devices. Construction shall be in accordance with attached drawings entitled FTC Model 10 Series Standard Neutron Source or FTC Model 100 Series Standard Neutron Source.

3. Radioactive Contents - No more than 192.0 GBq (5.2 Ci) of Californium-252. The Cf-252 is in the form of a Cf-Pd cermet or Cf-Pd alloy.

4. Quality Assurance - Records of Quality Assurance activities required by Paragraph 310 of the IAEA regulations[1] shall be maintained and made available to the authorized officials for at least three years after the last shipment authorized by this certificate. Consignors and consignees in the United States exporting or importing shipments under this certificate shall satisfy the requirements of Subpart H of 10 CFR 71.

5. Expiration Date - This certificate expires on January 31, 2011.

This certificate is issued in accordance with paragraph 804 of the IAEA Regulations and Section 173.476 of Title 49 of the Code of Federal Regulations, in response to the October 03, 2005 petition by Frontier Technology Corporation, Xenia, OH and in consideration of other information on file in this Office.

Certified By:

Jan 18 2006
(DATE)

Robert A. McGuire
Associate Administrator for Hazardous Materials Safetv

[1] "Regulations for the Safe Transport of Radioactive Material, 1996 Edition (Revised), No. TS-R-1 (ST-1, Revised)," published by the International Atomic Energy Agency(IAEA), Vienna, Austria.

[2] Title 49, Code of Federal Regulations, Parts 100-199, United States of America.

Revision 7 - Issued to add new outer dimension for Model 100 Series and update drawings.

Appendix C Thermal Test on a Sample of Cast Neutron Shielding

A test sample of polyester resin based Cast Neutron Shielding (CNS) was constructed in order to test the ability of this type of shielding to withstand fire.

Composition of Cast Neutron Shielding (CNS)

CNS has the following composition by weight

60% high-density polyethylene beads
20% Borax powder
20% Polyester resin plus catalyst

The components are well mixed when the polyester resin is in its liquid state. When hardened the CNS has a bulk density of approximately 1000 kg/m^3.

The Borax provides the Boron required for neutron shielding. It also acts as a fire retardant.

The Test Sample

A test sample was made by casting CNS into a steel box of dimensions 510mm square by 460mm high. This was the largest size of test sample which could fit into the test furnace (figure D1).

This sample simulates the way in which CNS is used in an analyser where it is cast into a steel enclosures within the body of the analyser.

This sample weighed 125 kg prior to the furnace test.

The Furnace Test

The furnace test was carried out at the premises of Australian Heat Treatment on 19th December 1996. Mr. John Brook of Brook Engineering witnessed the test (see attached statement).

The furnace was preheated to a temperature in excess of 800 degrees C. (see chart recorder trace). The sample was then placed in the furnace (figure D3). After a period of 30 minutes the sample was removed from the furnace and allowed to cool naturally. Flames were emitted from the sample when removed from the furnace but these had disappeared in less than two minutes (figures D4 to D6).

Examination of the Test Sample

When cooled the top was removed from the sample (figure 22) The surface of the CNS appeared as a uniform flat black surface.

Digging into the shielding revealed unmelted polyethylene less than 20mm below the surface. It appeared that the surface of the CNS had charred into an insulating crust which had protected the material below. (figures 23 and 24). Details of the examination were;

Top of sample

Depth	Appearance
0 - 10 mm	Powdery Black Char
10 - 15 mm	Brown scorched material
+ 15 mm	White appearance, unmelted beads

Side of sample

Depth	Appearance
0 - 14 mm	Powdery Black Char
14 - 19 mm	Brown scorched material
+ 19 mm	White appearance, unmelted beads

After the fire test the test sample weighed 114kg, indicating a weight loss of 11kg. This weight loss is attributed to volatilisation of the polyethylene and polyester in the charred outer layer of the shielding.

Technical Note

BROOK ENGINEERING PTY LTD
A.C.N. 052 138 184
13 Pleasant Grove, Holden Hill, S.A. 5088
Telephone: (08) 8264 3895
Facsimile: (08) 8396 4788

Statement by Witness to Fire Test

26/2/97

M.C.I. Pty Ltd
P.O. Box 64
Unley SA 5061

Telephone: (08) 8297 6144
Facsimile: (08) 8297 9305

Attention: Ken Smith

Fire Test Witnessing

Your PO No: 40574 Your Tool Ref: Our Ref: 96183 - 912
Your Ref: Fax 26/2/97

Subject: Statement by Witness of Fire Test

To Whom it May Concern

This is to certify that on 19th December 1996 I witnessed a furnace test on a test sample of polyester resin based Cast Neutron Shielding (CNS) at the premises of Australian Heat Treatment, 21 Arabrie Ave., Edwardstown, S.A., 5039.

The sample was placed in a furnace which was preheated to 800degrees celsius. After 30 minutes the sample was removed from the furnace.

On 23rd December 1996 I inspected the test sample at MCI Pty. Ltd. The outer surface of the Cast Neutron Shielding was charred, however unmelted polyethylene beads were found less than 20mm from the surface of the CNS.

J.F.H.Brook 26/2/97

Distribution
BE Job Manager: John Brook
G.M. then File

Regards

John Brook

1 of 1 Pages

Appendix E Radiation Survey Without Tunnel Extensions

NOTE: Radiation levels for the Front, Top, Rear and Bottom surfaces are unchanged when the tunnel extensions are removed. (See Figures 27 and 28)

BEAM ON Empty belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
B1	16	212	228	25	291	316	8	134	142
B2	18	771	789	55	715	770	13	190	203
B3	14	164	178	28	309	337	9	126	134
B4	6	7	13	15	106	121	8	112	119
B5	25	228	253	28	184	212	6	56	62
B6	85	1232	1317	55	529	584	11	69	80
B7	25	261	286	28	209	237	6	57	63
B8	4	11	15	11	79	90	6	48	54
B9	9	39	48	12	46	58	7	35	41
B10	37	106	143	21	139	160	9	49	58
B11	9	49	58	12	71	83	7	33	40
B12	4	8	12	7	31	38	6	27	32

BEAM ON Loaded belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
B1	16	85	101	19	80	99	8	31	39
B2	60	161	221	32	126	158	10	39	49
B3	18	83	100	20	82	102	7	30	37
B4	3	13	15	2	25	27	1	27	28
B5	40	111	151	25	117	142	8	23	31
B6	N/A	N/A	N/A	30	176	206	10	24	34
B7	42	111	153	23	111	134	8	22	30
B8	6	7	13	4	12	16	2	26	28
B9	17	22	39	16	23	39	7	16	23
B10	36	28	64	22	38	60	8	18	26
B11	19	23	41	15	23	38	7	15	22
B12	3	6	9	2	11	13	1	13	14

BEAM ON Empty belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
C1	5	7	12	14	110	124	8	106	114
C2	12	154	166	30	312	342	9	132	141
C3	18	790	808	52	710	762	12	186	198
C4	15	202	217	28	301	329	7	134	141
C5	4	10	14	10	84	94	6	43	49
C6	22	272	294	30	215	245	6	62	68
C7	80	1220	1300	55	518	573	10	65	75
C8	28	220	248	26	178	204	6	52	58
C9	4	7	11	7	28	35	6	32	38
C10	8	52	60	12	75	87	7	29	36
C11	38	102	140	18	122	140	9	45	54
C12	9	42	51	10	44	54	7	32	39

BEAM ON
Loaded belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
C1	2	14	16	2	24	26	1	25	26
C2	20	78	98	18	86	104	6	32	38
C3	55	155	210	30	132	162	9	42	51
C4	18	90	108	18	78	96	8	28	36
C5	6	8	14	4	10	14	2	28	30
C6	40	118	158	22	105	127	8	19	27
C7	N/A	N/A	N/A	30	175	205	10	22	32
C8	39	117	156	26	112	138	8	24	32
C9	3	5	8	2	12	14	1	12	13
C10	17	24	41	15	24	39	7	16	23
C11	34	28	62	20	40	60	8	21	29
C12	16	23	39	17	20	37	8	15	23

Appendix F Radiation Survey With Automatic Source Drive Option (See Figures 29 to 34)

BEAM ON Empty belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
A1	2	6	8	2	5	7	1	4	4
A2	4	6	9	2	4	6	2	3	5
A3	2	4	6	2	4	6	2	4	6
H1	9	23	32	8	11	19	2	3	5
H2	7	9	16	5	9	14	2	4	6
H3	5	8	13	4	7	11	1	3	4
H4	10	11	21	7	7	14	3	4	7
H5	6	4	10	5	6	11	2	4	6
H6	5	4	9	4	5	9	2	3	5
H7	7	9	16	5	7	12	4	5	9
H8	7	8	15	5	5	10	4	4	8
H9	5	6	11	4	4	8	3	4	7

BEAM OFF Empty belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
A1	0	0	0	0	0	0	0	1	1
A2	1	0	1	0	0	0	0	1	1
A3	0	0	0	0	0	0	0	0	0
H1	1	1	2	0	0	0	0	3	3
H2	2	1	3	0	0	0	0	2	2
H3	1	0	1	0	2	2	0	1	1
H4	0	1	1	0	0	0	0	0	0
H5	0	1	1	0	0	0	0	0	0
H6	0	0	0	0	1	1	0	0	0
H7	0	0	0	0	1	1	0	1	1
H8	0	0	0	0	0	0	0	1	1
H9	0	0	0	0	1	1	0	1	1

BEAM ON Empty belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
B1	24	83	107	17	53	70	9	27	36
B2	29	91	120	20	74	94	10	27	37
B3	22	73	95	16	45	61	9	23	32
B4	6	7	13	7	9	16	5	8	13
B5	22	58	80	16	40	56	9	20	29
B6	29	55	84	20	46	66	9	19	28
B7	24	42	66	16	32	48	9	24	33
B8	4	11	15	6	4	10	5	4	9
B9	16	33	49	13	32	45	7	23	30
B10	18	41	59	13	35	48	7	30	37
B11	16	33	49	11	22	33	4	24	28
B12	4	8	12	7	8	15	5	6	11
B13	33	8	41	32	8	40	3	6	9
B14	22	5	27	19	4	23	3	5	8
B15	8	2	10	7	2	9	3	3	6

BEAM OFF Empty belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
B1	3	2	5	2	2	4	1	1	2
B2	3	2	5	2	1	3	1	1	2
B3	4	2	6	2	2	4	0	1	1
B4	0	0	0	1	0	1	1	0	1
B5	3	2	3	3	1	4	2	2	4
B6	2	3	3	2	2	4	1	1	2
B7	2	2	2	2	1	3	1	1	2
B8	1	0	1	2	0	2	1	0	1
B9	4	2	6	3	1	4	2	1	3
B10	3	2	5	3	2	5	2	2	4
B11	1	1	2	2	2	4	1	1	2
B12	0	0	0	1	1	2	0	0	0
B13	2	2	4	2	2	4	1	1	2
B14	10	6	16	6	1	7	2	1	3
B15	22	6	28	10	2	12	2	0	2

BEAM ON Empty belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
C1	5	7	12	7	9	16	5	8	13
C2	22	73	95	16	45	61	9	23	32
C3	29	91	120	20	74	94	10	27	37
C4	24	83	107	17	53	70	9	27	36
C5	4	10	14	6	4	10	5	4	9
C6	24	42	66	16	32	48	9	24	33
C7	29	55	84	20	46	66	9	19	28
C8	22	58	80	16	40	56	9	20	29
C9	4	7	11	7	8	15	5	6	11
C10	16	33	49	11	22	33	4	24	28
C11	18	41	59	13	35	48	7	30	37
C12	16	33	49	13	32	45	7	23	30
C13	33	8	41	32	8	40	3	6	9
C14	22	5	27	19	4	23	3	5	8
C15	8	2	10	7	2	9	3	3	6

BEAM OFF Empty belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
C1	0	0	0	1	0	1	1	0	1
C2	4	2	6	2	2	4	0	1	1
C3	3	2	5	2	1	3	1	1	2
C4	3	2	5	2	2	4	1	1	2
C5	1	0	1	2	0	2	1	0	1
C6	2	2	2	2	1	3	1	1	2
C7	2	3	3	2	2	4	1	1	2
C8	3	2	3	3	1	4	2	2	4
C9	0	0	0	1	1	2	0	0	0
C10	1	1	2	2	2	4	1	1	2
C11	3	2	5	3	2	5	2	2	4
C12	4	2	6	3	1	4	2	1	3
C13	2	2	4	2	2	4	1	1	2
C14	10	6	16	6	1	7	2	1	3
C15	22	6	28	10	2	12	2	0	2

BEAM ON Empty belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
D1	1	2	3	1	4	5	0	2	2
D2	1	1	2	1	2	3	0	3	3
D3	1	1	2	1	2	3	0	4	4
D4	1	0	1	2	1	3	0	2	2
D5	1	2	3	1	1	2	1	3	4
D6	1	2	3	0	2	2	1	2	3
D7	0	2	2	1	2	3	0	2	2
D8	0	2	2	0	2	2	0	1	1
D9	0	2	2	1	2	3	0	3	3

BEAM OFF Empty belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
D1	1	1	2	1	0	1	0	0	0
D2	1	1	2	1	0	1	0	1	1
D3	1	0	1	0	1	1	0	0	0
D4	4	0	4	3	1	4	1	1	2
D5	5	1	6	3	1	4	1	1	2
D6	4	0	4	3	1	4	1	1	2
D7	6	0	6	3	1	4	1	2	3
D8	7	1	8	3	1	4	1	0	1
D9	6	0	6	3	0	3	1	1	2
I1	1	1	2	2	0	2	1	1	2
I2	2	1	3	2	1	3	0	1	1
I3	1	1	2	1	1	2	1	0	1
I4	8	4	12	7	3	10	2	0	2
I5	3	1	4	4	1	5	1	0	1
I6	1	0	1	3	1	4	1	0	1
I7	13	5	18	9	2	11	1	0	1
I8	6	2	8	6	2	8	1	1	2
I9	1	1	2	3	1	4	1	2	3

BEAM ON Empty belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
E1	9	66	75	8	82	90	3	35	38
E2	20	99	119	10	92	102	5	31	36
E3	9	65	74	8	84	92	4	37	40
E4	8	45	53	7	46	53	4	24	28
E5	8	66	74	5	45	50	4	14	18
E6	8	44	52	8	48	56	4	22	26
E7	8	65	73	7	86	93	4	38	41
E8	21	98	119	10	90	100	5	29	34
E9	9	66	75	9	85	94	3	39	42
E10	2	6	8	1	3	4	2	6	8
E11	2	7	9	2	6	8	2	8	10
E12	2	7	9	1	3	4	2	7	9
E13	1	2	3	1	6	7	1	2	3
E14	1	2	3	2	4	6	1	2	3
E15	1	1	2	2	3	5	1	1	2
G1	4	7	11	2	7	9	2	11	13
G2	4	12	16	3	8	11	2	6	8
G3	4	9	13	3	6	9	1	4	5
G4	11	20	31	5	20	25	2	22	24
G5	10	25	35	7	15	22	3	12	15
G6	5	9	14	4	12	16	1	9	10
G7	5	7	12	2	8	10	2	10	12
G8	5	11	16	3	10	13	1	6	7
G9	3	9	12	3	5	8	2	4	6

BEAM OFF Empty belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
E1	2	1	3	2	1	3	0	0	0
E2	2	1	3	2	1	3	0	1	1
E3	2	1	3	2	1	3	1	1	2
E4	2	0	2	2	1	3	1	1	2
E5	1	1	2	2	2	4	0	1	1
E6	2	1	3	2	1	3	0	1	1
E7	0	0	0	2	1	3	0	1	1
E8	0	0	0	3	1	4	1	1	2
E9	0	0	0	2	1	3	0	1	1
E10	0	1	1	0	1	1	0	0	0
E11	0	0	0	0	1	1	0	0	0
E12	0	0	0	0	0	0	0	0	0
E13	1	0	1	1	1	2	0	1	1
E14	1	1	2	1	0	1	1	1	2
E15	1	1	2	1	0	1	0	1	1
G1	6	0	6	2	1	3	0	0	0
G2	7	1	8	2	1	3	0	1	1
G3	3	1	4	2	1	3	0	1	1
G4	3	1	4	1	1	2	0	2	2
G5	4	1	5	1	1	2	0	1	1
G6	0	1	1	2	0	2	0	1	1
G7	1	0	1	0	0	0	0	1	1
G8	2	1	3	2	0	2	0	1	1
G9	2	1	3	3	1	4	0	0	0

BEAM ON Empty belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
F1	3	9	12	5	9	14	5	11	16
F2	7	9	16	7	14	21	4	10	14
F3	4	9	13	4	8	12	4	11	15
F4	17	34	51	14	28	42	6	12	18
F5	36	76	112	22	42	64	6	13	19
F6	18	35	53	13	26	39	5	12	17
F7	3	8	11	5	8	13	5	12	17
F8	8	9	17	6	14	20	4	9	13
F9	4	8	12	5	8	13	4	12	16
F10	2	6	8	4	6	10	3	8	11
F11	5	5	10	5	9	14	4	7	11
F12	3	4	7	4	6	10	3	7	10

BEAM OFF Empty belt radiation dose rates in µSv/hr for 50µg of Cf-252

	5cm			30cm			100cm		
	Gamma	Neutron	Total	Gamma	Neutron	Total	Gamma	Neutron	Total
F1	1	4	5	2	7	9	4	9	13
F2	2	5	7	5	12	17	3	8	11
F3	1	4	5	2	6	8	3	9	12
F4	3	10	13	5	9	14	5	11	16
F5	8	10	18	7	14	21	4	10	14
F6	3	9	12	4	8	12	4	11	15
F7	18	35	53	15	28	43	5	12	17
F8	35	74	109	20	42	62	6	13	19
F9	18	34	52	14	26	40	6	12	18
F10	13	30	43	12	25	37	4	10	14
F11	30	68	98	18	41	59	4	11	15
F12	14	28	42	13	24	37	4	10	14

2016201678 20 May 2016

APPENDIX III

On Belt Analyser

Installation Manual

Version 7.3

October 2005

Scantech International Pty Ltd
ABN 56 087 557 426
143 Mooringe Avenue
Camden Park SA 5038 AUSTRALIA
Tel: +61 8 8350 0200 Fax: +61 8 8350 0188

2016201678 20 May 2016

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About This Manual

Contents of this Manual

This manual is intended to provide sufficient information to enable the client to prepare his site and install the analyser. It contains:

1. an introduction to the On Belt Analyser and brief description of how it works
2. receipt and storage requirements
3. site requirements and radiation safety
4. environmental requirements
5. installation instructions

Conventions

This manual uses the following symbols and conventions:

➢	a list item
☞	an action to take
1.	a step in a procedure, where the order is important

> *Text in boxes:* Additional information or warnings requiring special attention.

1

Introduction

Introducing the On Belt Analyser

The On Belt Analyser measures the elemental composition of material passing through on a standard conveyor belt. Microwave moisture measurement is available as an optional extra.

The analyser can be used for applications such as sorting and stockpile blending.

Measurements are made on-line and real-time results are obtained. Results are produced as frequently as every one minute and are available from a Modbus TCP/IP Ethernet or optical fibre connection.

Description

The On Belt Analyser is a compact unit which is weather and impact resistant. As shown in Figure 35, the Analyser includes:

- A heavily shielded section that contains the radioactive neutron source and a gamma ray detection assembly. The source is installed below the centre of the tunnel.
- The steel housing contains the radiation shielding material and neutron moderators. The suspended belt travels through a tunnel without contact to any part of the analyser. The empty return belt travels underneath the analyser.
- The electronics cabinet is temperature controlled and contains the analyser computer, modem, I/O modules, UPS, power supplies and circuit breakers.

Operating Principle

The On Belt Analyser uses a thermal neutron capture and gamma ray production technique known as *PGNAA* (Prompt Gamma Neutron Activation Analysis).

A neutron source inside the instrument emits neutrons that irradiate the material on the conveyor belt passing through the analyser. Neutrons are absorbed by the nuclei of elements in the material. This results in an immediate or "prompt" release of energy. This energy is radiated away from the nucleus by the emission of several gamma rays, each with a distinct energy.

The success of this technique relies on the fact that the gamma rays produced have characteristic, discrete energies, which are unique to each nuclear species. For example, the gamma rays produced by calcium have different energies to those produced by silicon, and so on.

The optional microwave gauge provides accurate moisture measurement utilising group delay and attenuation of microwaves transmitted through the material on the conveyor belt.

Data Display

The On Belt Analyser outputs results and status information using the Modbus TCP/IP protocol via an Ethernet or optical fibre connection. There are two options available for viewing results generated by the analyser:

Optional superSCAN (supplied by Scantech)

The superSCAN computer provides display and reporting features. It uses a SCADA package called iFIX which runs on Microsoft Windows. The superSCAN computer is normally located in a plant control room.

superSCAN includes:

- Personal Computer with Ethernet port
- Monitor, keyboard and mouse
- Colour printer
- superSCAN software with standard configuration.

Optional Plant Interface (supplied by the client)

The analyser results and status can be output directly to the plant control system using the Modbus TCP/IP Ethernet or optical fibre connection. Other forms of outputs to the plant are available on request.

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Receipt and Storage Requirements

Receiving the Shipment

When the shipment arrives, check that the packing is undamaged and that the shipment is complete. If any damage is found or any components are missing, report this immediately to Scantech and to the shipping company.

Storage Requirements

If the client must store the analyser outdoors before installation, it must be powered on with the weather protection roof installed, unless there is no rain, hail or snow and the ambient temperature is between +15°C and +25°C.

Failure to meet this requirement may cause thermal shock to the detectors, voiding the warranty.

Storing the Calibration Standards

It is necessary to store the calibration standards near the analyser since they may be used frequently during commissioning. In normal operation, the standards may be used at intervals of 6–12 months, depending on site requirements and conditions.

The storage site chosen for the standards should keep them clean and protect them from the elements. There are no other special requirements, but the client must consider the standards as vital to the precision of the analyser, and treat them accordingly.

Storing the Radioactive Source

The Californium-252 neutron source is shipped separately and loaded into the analyser during commissioning. The client must provide temporary storage for the source in accordance with local regulations until such time that it can be loaded into the analyser.

The source is a small stainless steel capsule, delivered to site in a shielded transport container. The transport container is typically a 44 Gallon drum and weighs approximately 250 kg.

The transport container is returned to the source manufacturer after the source is loaded into the analyser.

Scantech supply a separate source storage/loading drum with the analyser. This is used for loading source capsules into the analyser and for storing the source when it is removed from the analyser for maintenance.

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Site Requirements

Location Requirements

For the On Belt Analyser to be an effective process control tool, the client must choose its location carefully, making sure that the analyser is close enough to the control devices to meet the process control requirements. The client must consider:

- the relationship of the analyser to the other components of the system such as belt weigh scale and feeders
- the equipment response time — Is it fast enough for the process control requirements?
- belt speed and process lag times
- the position of the belt weigher

> ***Note:*** *If the On Belt Analyser is installed more than 30 seconds before the belt weigher a bed depth sensor must be used.*

Inputs Required

The On Belt Analyser requires the following inputs:

- Analogue signal from the belt weigher for Tonnes Per Hour. It is not essential that the timing of weight information coincides with material passing through the analyser. This time lag can be compensated in the analyser computer.
- Analogue signal from the belt tachometer (only required if belt speed variable)
- Analogue signal from bed depth sensor (only required if the analyser is installed more than 30 seconds before the belt weigher)
- Clean contact input for belt run indicator
- Clean contact inputs for stockpile selection and resetting (only required for stockpile applications) Analogue inputs are required as 4–20 mA current loops.

Ensure that plant equipment signals do not exceed the analyser isolation voltage and current ratings.

Outputs

- Clean contact indicating System OK (no critical alarms)
- Analyser results and status are transmitted to the plant or superSCAN computer using a Modbus TCP/IP Ethernet or optical fibre connection

Engineering Requirements

The installation drawing supplied with this manual gives the client information to prepare the site and install the analyser. The client should review this drawing and consult with Scantech about any requirements that are unclear.

The dimensions of one embodiment of the On Belt Analyser as shown in Figure 36.

Approximate Installed Mass

The total approximate installed mass of the On Belt Analyser is 2500 kg.

Clearances Required

A clearance is required above the analyser to enable access to the detector enclosure and air conditioner units. The client must also ensure sufficient clearance is available to allow access to the electronics cabinet.

The required clearances are shown in the installation drawing.

Note that the clearances are also required after installation, to allow any maintenance required and source loading.

Lifting Equipment Required

The On Belt Analyser is to be lifted at the 4 lifting points at the top corners of the analyser. Eye bolts are supplied with the analyser for easy installation. All lifting equipment must be approved and comply with local regulations.

On Belt Analyser Support Requirements

The analyser must be installed in accordance with the installation drawing in the Appendix. A structural steel frame, columns, or beams can be used as long as the analyser is supported *around the entire perimeter* of its base. It is not sufficient to support the analyser from the corners only. The analyser must be secured at the four M20 hold-down bolt holes.

The structural steel must be capable of supporting the weight of the analyser in accordance with the local requirements.

The support structure must provide a minimum of 250mm clearance beneath the analyser for the return belt. Refer to the installation drawing.

Material Requirements

The On Belt Analyser design provides limited protection from impact to the detectors. The analyser can tolerate surging and handle bed depths up to 280mm.

If larger rocks / high bed depths are likely, a steel plough before the analyser is recommended to protect it from damage.

Since materials, material transport and handling procedures vary from plant to plant, the client must complete and return the On Belt Analyser Questionnaire and return it to Scantech.

Belt Requirements

The On Belt Analyser can be fitted on existing conveyors and accepts all standard conveyor belt sizes from 600 mm to 1400 mm. The maximum lateral belt drift must satisfy Australian standards. Steering idlers may be required.

Belt Width	Maximum Lateral Drift
600 mm	±40 mm
800 mm	±40 mm
1000 mm	±50 mm
1220 mm	±60 mm
1400 mm	±70 mm

The analyser will work with most types of conveyor belts.

Return Belt Idlers

A return idler system is required for the empty return belt. The client must supply two idlers underneath the analyser, and some alterations may be required to the existing conveyor system. The return belt must be a minimum of 75 mm from the underside of the analyser.

Calibration Standards

As shown in Figure 387, Scantech supplies a specially manufactured calibration container and bagged client samples to verify the analyser calibration.

Belt width (mm)	A (mm)	B (mm)	C (mm)
600	1500	650	250
800	1500	650	250
1200	1500	750	250
1400	1500	860	250

The conveyor belt must be clean and empty before calibration standards are placed on it. The client must supply a winch for pulling the calibration standards into the centre of the analyser tunnel. A conveyor belt inching motor may be used in place of a winch.

Increased radiation levels are present near the tunnel openings.

Personnel should never enter the tunnel while the source is in the BEAM ON position. Either remove the source rod and store it in the supplied storage drum or force it to the BEAM OFF position if an optional automatic source drive is installed.

Special Installations

If the client is installing the On Belt Analyser on an open conveyor, in an elevated position or on an inclined belt, he must carefully consider the following points.

Installing on an Open Conveyor

If installing the analyser on a conveyor in open space it is important to restrict access to the entrance and exit of the analyser tunnel, as there is a danger of radiation exposure, when the tunnel is empty.

Access to the area around the tunnel openings should be restricted and well marked with radiation signs. If access is required in this area then the source should be removed and stored in the supplied source storage/loading drum or driven to the BEAM OFF position if an optional source drive is installed.

Refer to the Health and Safety Review for radiation levels.

Installing in an Elevated Position

If installing the analyser in an elevated position, the client must ensure that access to the underside of the analyser is restricted by a lockable enclosure or other device, since there is a danger of radiation exposure.

The restricted area must be well marked using radiation warning signs.

If access is required to the restricted area, the client must monitor the exposure time, and follow all local radiation safety regulations. Additional shielding can be installed to reduce the radiation levels.

Power Supplies

The power supplied to the analyser must be in accordance with the following. The cable entry points are on underside of the electronics cabinet, as shown on the installation drawing.

Electronics Cabinet Power Supply

230 Volts AC, +10%, –15%

15 Amps

Momentary power failure less than 10 msec

50/60 Hz ± 1 Hz

Less than 5% total harmonic distortion

Less than 3% any single harmonic distortion

The analyser is equipped with an uninterruptible power supply (UPS) to allow an orderly shutdown of the analyser computer software and drive the source to the BEAM OFF position if an optional automatic source drive is installed.

A continuous power supply is desirable for optimum operation of the analyser. When selecting the power circuit the most reliable circuit should be chosen.

Telephone and Modem Requirements

A modem is supplied in the electronics cabinet for remote connection to the analyser computer (for diagnostics, calibration maintenance and upgrading software). The client must connect the modem to a dedicated telephone line that can be dialled directly from Scantech.

***Important:** Remote modem access is essential during commissioning and cannot normally operate through a PABX system. The On Belt Analyser purchaser must supply a dedicated data quality line providing a baud rate of 9600bps.*

SuperSCAN Computer

The optional superSCAN computer must be located in a clean environment such as an office or plant control room. It may be located up to 100 metres from the analyser, or further if repeaters or optical fibre is used.

Environmental requirements are: Temperature: +4 to +40°C

Vibration:	<0.05 G at 23 to 500 Hz
Shock:	5 G at 10 msec maximum
Humidity:	10 – 80%, non-condensing
Atmosphere:	non-corrosive
Power:	single phase 110 Volts AC, 10 Amps or
	single phase 230 Volts AC, 5 Amps

A UPS is recommended for the superSCAN computer to ensure that an orderly shut down without data loss can be achieved if the power fails.

Cabling Requirements

The client must supply the following cables (as per the cable schedule in the electrical assembly drawings):

- standard network cable (UTP Cat5) from the plant Control System or superSCAN computer to the analyser.
- cabling from the analyser to any plant equipment it is required to control or monitor by digital signals
- cabling from the analyser to the belt weigher, belt tachometer, bed depth sensor and any other plant equipment are required to support analogue or clean contact signals
- cabling for data quality telephone line

The cable entry point is on the underside of the electronics cabinet, as shown on the installation drawing.

Wiring Ferrule Numbers

Wiring ferrule numbers used in the analyser should not be changed to another numbering system, for the following reasons:

⇒ *Ease of Maintenance* — Scantech service personnel are familiar with the numbering system used in the analyser and this reduces down time for maintenance.

⇒ *Safety* — Using the standard wiring ferrule numbers reduces the chances of accidents.

Site Requirements Checklist

Complete the following checklist by ticking each box as each site preparation requirement is achieved or confirmed:

Site Requirement	Tick the box
Tonnes Per Hour signal is available at the analyser.	☐
Tonnes Per Hour signal has a response time less than the response time of the device used to load the conveyor belt which the analyser is installed on.	☐
Cabling between the analyser and plant system (or superSCAN) has been tested for clean data transmission and is available at both ends.	☐
(For variable speed belts) Belt Speed signal is available at the analyser.	☐
Belt run signal is available at the analyser.	☐
Cable from a stable power supply at the correct rating is available at the analyser.	☐
Dedicated data quality telephone line (> 9600bps) for modem access is available at the analyser.	☐
Access is possible and equipment is available for installing the side shield.	☐
(For elevated installations) Lockable means of restricting access to the underside of the analyser is in place and radiation warning signs are fitted.	☐
(For open area installation) Access to the tunnel entrance and exit restricted.	☐
(For open area installation) Weather protection roof is ready to install.	☐
Temporary location is available for the source transport container near the analyser's electronics cabinet during the source loading procedure.	☐
Permanent location is available for the source storage/loading drum near the analyser's electronics cabinet.	☐
Permanent storage is available for the calibration standards.	☐
Location is available for the superSCAN computer.	☐
Holding down bolts are available. They must be manufactured from corrosion resistant mild steel or stainless steel.	☐

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Environmental Requirements

General Requirements

The On Belt Analyser is designed to be installed outside, and within reasonable distances from other machinery. The client must ensure that there are no objects near the analyser blocking the air conditioning vents and note the following additional environmental requirements:

Temperature

Operating temperatures are to be between –40°C and +50°C.

Vibration

0 – 2.5G at 10 to 100 Hz, 0.5 mm.

If vibration is expected to exceed this specification, the client should consider a different location for the analyser. The analyser performance cannot be guaranteed outside these conditions.

Shock

The limit is 3G, three times in three directions, one millisecond

Humidity

No special requirements. The analyser handles humidity from 0 to 100 %.

Altitude

The analyser is designed for installation below 3000 metres.

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Installation

The On Belt Analyser is simple to install because it is small and compact. The analyser can be installed by Scantech, the client or by its contractors, following Scantech guidelines.

Installation procedures are:

- *Mechanical installation*
- *Electrical installation*
- *Installation checklist*
- *Pre-commissioning checklist* — carried out by client prior to an engineer departing Scantech
- *Commissioning and acceptance testing* — carried out by Scantech with the assistance of the client

A complete set of installation drawings is supplied with this manual. The client should be familiar with these drawings before beginning the installation. The client should contact Scantech if they have any queries or are uncertain about any of the procedures.

Unloading the On Belt Analyser

Unloading with a Forklift

The analyser is shipped on a timber pallet which has forklift slots.

Unloading with a Crane

The analyser can also be lifted using slings attached to the four lifting points. All lifting equipment must approved and comply with local regulations.

Installing the On Belt Analyser

Mechanical Installation

- ☞ Remove approximately a 1.1 metre section of the steelwork supporting the conveyor, at the position where the analyser is to be installed. Refer to the installation drawing.
- ☞ If a belt is already installed, it may be necessary to raise its counterweight and pull it to one side.
- ☞ Unbolt the side shield and remove from the analyser.
- ☞ Lift the analyser into position, using slings attached to the four lifting points.
- ☞ Check that the analyser is aligned correctly.
- ☞ Install hold down bolts.
- ☞ Check clearances around the analyser as shown on the installation drawing.
- ☞ Position the belt into the analyser tunnel so that the belt is centred and there is a 30mm clearance between the underside of the belt and analyser tunnel base.
- ☞ Reinstall the side shield and bolt it in place as per Figure 4.
- ☞ Reposition the return belt to clear the underside of the analyser.
- ☞ Install the radiation tunnel shield around the tunnel openings.
- ☞ Install the source drive shield if automatic source drive is supplied.
- ☞ Install the weather protection roof (only supplied if analyser is otherwise unprotected from the weather).
- ☞ Bolt the optional microwave antennae frame to the steelwork supporting the conveyor within 5 metres of the analyser frame. If it’s installed upstream the analyser, ensure it’s downstream of the steel plough.
- ☞ Ensure the microwave antennae are centred on the belt as per Figure 5.

Electrical Installation

All cables crossing open ground must be carried underground in conduit.

Communication lines in and out of the analyser are fitted with transient protection against low level noise, and with protection from lightning induced over-voltages.

To complete the electrical installation:

- ☞ Determine cable routes. The cabling used must be in accordance with the analyser electrical assembly drawings. Three major cable routes are required:

1. Plant to the analyser electronics cabinet, power and signal
2. The analyser electronics cabinet to the plant system or superSCAN computer
3. The optional microwave antennae frame to the analyser electronics cabinet.

- ☞ Locate the source of the power supply and required inputs for the electronics cabinet.
- ☞ Determine the location of the superSCAN computer and its power supply source.
- ☞ Route the cable from the optional microwave antennae frame to the analyser electronics cabinet. Terminate wiring as per the Plant Interface Wiring Diagram.
- ☞ Install all cable ladders, conduits, cable supports and mechanical protection.
- ☞ Carry out any wall or floor penetrations.
- ☞ Install and secure all cabling, leaving sufficient length at each end for termination.
- ☞ Terminate all cabling at electronics cabinet.
- ☞ Unpack the superSCAN computer and install at the desired location.
- ☞ Terminate cabling at the superSCAN computer.
- ☞ When mechanical installation of the analyser has been completed, identify, mark and terminate all wiring.

Installation Checklist

The On Belt Analyser is installed when all the items in the following table are operational:

Installation requirement	**Tick the box**
The analyser is installed on the conveyor belt as shown in the installation drawing.	☐
Power and plant interface cables are terminated at the electronics cabinet. Power supply must be stable.	☐
The side shield is installed and secured.	☐
The conveyor belt is correctly aligned so that the belt is centred and there is a 30mm clearance between the underside of the belt and analyser tunnel base.	☐
A radiation licence has been granted and the source has arrived at site.	☐
The modem is operational.	☐

Pre-Commissioning Checklist

The following items must be completely installed and/or operational before the Scantech Field Engineer arrives to complete the analyser installation. Please complete the checklist and fax a copy to Scantech on (+618) 8350 0188.

> ***Warning:*** *Failure to confirm the items and complete the checklist may result in delays in commissioning and/or additional service charges.*

Material handling

Site Requirement	Tick the box
The analyser is mechanically installed in accordance with the instructions in this manual.	☐
The necessary time for static calibration testing has been allocated in the production schedule.	☐
All material handling equipment is installed and operational. This includes crushers, weigh scale inputs, etc.	☐
Material is available for flow through the analyser.	☐
A steel plough is installed before the analyser if the material bed depth exceeds 280mm during surging.	☐

Radioactive sources

Site Requirement	Tick the box
Radioactive source arrived on site. Date: ___________	☐
Radioactive source is stored near the analyser. (If not, the proper equipment is available to move the sources near the analyser.)	☐

Electrical and connections

Site Requirement	Tick the box
The analyser electrical power is installed and tested. ☐ Tested voltages: _________VAC ±___________ % ☐ _________Hz ± ___________ %	☐
All essential plant inputs are wired and operational. ☐	TPH Tacho Belt Run

Electrical and connections (cont'd)

Site Requirement	Tick the box
A direct dial modem telephone line is connected: Number:	
The interconnecting cabling between the analyser and superSCAN is installed.	
Power is available to superSCAN: VAC: _______ Hz: ______	

Sampling and testing

Site Requirement	Tick the box
Suitable storage is available for the calibration standards.	
Will sampling of the material be done using an automatic or manual sampler, or is there no sampling system available? Indicate the location of the sampler within the material flow stream (Attach drawings). ________________________________ ________________________________ ________________________________	Auto Manual None
Site XRF laboratory fully functional. (If not, arrangements have been made for all collected samples to be analysed by XRF.)	

For reference

Is on-site accommodation available?	
Is transportation to the site available? Or should a rental car be arranged?	Avail. Rental
Is site access available 24 hours/day, 7 days/week? (If not, what is the availability? ________________________________)	

Signed: ______________________________ Date: ______________

Title: ______________________________

Commissioning and Acceptance Testing

The On Belt Analyser is commissioned by Scantech's service engineer, who will attend site after installation is completed. Commissioning includes:

- mechanical checks
- electrical checks
- modem and data communication checks
- plant interface checks
- installation of the radioactive source
- thorough testing of all components
- software testing and configuration
- setting up superSCAN computer or assisting with Modbus TCP/IP communications to plant

The analyser is calibrated and tested in the factory before being shipped. After factory acceptance testing, the client samples used in the calibration will be shipped to the site for use as permanent calibration standards.

During commissioning and acceptance testing the calibration is verified on site to ensure that the same results are obtained.

Material must be available for delivery to the analyser before dynamic calibration work can begin.

Appendices

A — Drawings

The following drawings are supplied with the On Belt Analyser:

Drawing	Title
9560-00-0061	Installation - On Belt Analyser
9560-00-0064	Installation - Typical Conveyor Modification
9990-GA-0010	General Assembly – On Belt Analyser
9990-EL-0010	Plant Interface Wiring – On Belt Analyser

B — Radiation Safety

A complete description of the On Belt Analyser radiation safety features can be found in the report titled, "Health and Safety Review" available from Scantech.

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A bulk material analyser configured to analyse bulk material in the form of coal, minerals, cement raw materials, or the like, including:

an enclosed tunnel for receiving a conveyor belt carrying a bulk material to be analysed, the enclosed tunnel having a roof, a base and walls that together form a closed loop around the conveyor belt;

a neutron source to emit neutrons into the material in the tunnel for interaction with the material disposed therein; and

a gamma ray detector to detect gamma rays emitted from the material in response to the neutron interaction;

wherein the conveyor belt passes through the tunnel in an elevated position relative to the base of the tunnel.

2. A bulk material analyser configured to analyse bulk material in the form of coal, minerals, cement raw materials, or the like, carried on a conveyor belt, the analyser including:

an enclosed tunnel for receiving the conveyor belt, the enclosed tunnel having a roof, a base and walls that together form a closed loop around the conveyor belt when installed;

a neutron source to emit neutrons into the material in the tunnel for interaction with the material disposed therein; and

at least one gamma ray detector to detect gamma rays emitted from the material in response to the neutron interaction;

wherein the analyser is configured to allow the conveyor belt to travel through the tunnel, in use, in an elevated position relative to the base of the tunnel.

3. The bulk material analyser of claim 1 or 2, wherein the analyser is configured to allow the conveyor belt to travel through the tunnel in freely suspended relation so that neither the belt nor the base of the tunnel is subject to wear within the tunnel.

4. A bulk material analyser configured to analyse bulk material in the form of coal, minerals, cement raw materials, or the like, and being adapted to be positioned across a path of a conveyor belt which carries bulk material to be analysed, the analyser including a neutron source and at least one gamma ray detector, wherein the analyser defines an enclosed tunnel, and the conveyor belt carrying bulk material to be analysed in use passes between the neutron source and the gamma ray detector and through the tunnel in an elevated position relative to a base of the tunnel.

5. A bulk material analyser configured to analyse bulk material in the form of coal, minerals, cement raw materials, or the like, including a neutron source, at least one gamma ray detector, wherein the analyser defines an enclosed tunnel and is adapted to be positioned across a path of a conveyor belt which carries bulk material to be analysed, such that in use the belt passes through the tunnel in an elevated position relative to a base of the tunnel, the portion of the conveyor belt within the tunnel being suspended between supports external of the tunnel.

6. The bulk material analyser of any one of claims 1 to 5, wherein the analyser is adapted to be positioned across a path of an existing conveyor belt without disrupting the existing conveyor belt.

7. The bulk material analyser of any one of claims 1 to 6, wherein the analyser includes a C-shaped portion and a removable side portion to close the open side of the C-shaped portion and thereby define the enclosed tunnel and allowing the analyser to be retro-fitted across a bulk material conveyor belt.

8. The bulk material analyser of any one of claims 1 to 7, wherein the tunnel is configured to receive a belt of between 600 mm and 1400 mm in width, with a trough angle of between 30° and 45° without requiring any modification to the belt profile.

9. The bulk material analyser of any one of claims 1 to 8, including a conveyor assembly with idlers arranged to support the belt at either side of the enclosed tunnel so as to suspend the belt in an elevated position relative to the base of the enclosed tunnel as the

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belt passes through the tunnel.

10. The bulk material analyser of claim 9, wherein the idlers are spaced at between 1.2 and 1.5 metres apart.

11. The bulk material analyser of any one of claims 1 to 10, wherein the width of the analyser, in a direction lengthwise of the conveyor belt, is in the order of 1 metre.

12. The bulk material analyser of any one of claims 1 to 11, arranged whereby a clearance in the order of 30 mm is provided between the belt carrying bulk material and a base of the tunnel.

13. The bulk material analyser of any one of claims 1 to 12, including extension panels to provide protection adjacent to the analyser and external of the tunnel, from radiation emissions generated by the neutron source within the analyser.

14. A bulk material analyser configured to analyse bulk material in the form of coal, minerals, cement raw materials, or the like, including:

an enclosed tunnel for receiving a conveyor belt carrying a bulk material to be analysed, the enclosed tunnel having a base and walls that together form a closed loop around the conveyor belt;

a neutron source to emit neutrons into an interaction region within the enclosed tunnel for interaction with a bulk material disposed therein; and

at least one gamma ray detector to detect gamma rays emitted from the material in response to the neutron interaction;

wherein the conveyor belt carrying the bulk material passes through the enclosed tunnel in an elevated position relative to the base of the tunnel.

15. A bulk material analyser configured to analyse bulk material in the form of coal, minerals, cement raw materials, or the like, including:

an enclosed tunnel for receiving a conveyor belt carrying a bulk material to be analysed, the enclosed tunnel having a base and walls that together form a closed loop around the conveyor belt when installed;

a neutron source to emit neutrons into an interaction region within the enclosed tunnel for interaction with a bulk material disposed therein; and

at least one gamma ray detector to detect gamma rays emitted from the material in response to the neutron interaction;

wherein the analyser is configured to allow the conveyor belt carrying the bulk material to travel through the enclosed tunnel in an elevated position relative to the base of the tunnel.

16. The bulk material analyser of claim 14 or 15, wherein the conveyor belt carrying the bulk material is unsupported between the neutron source and the at least one gamma ray detector.

17. The bulk material analyser of claim 14 or 15, wherein the conveyor belt carrying the bulk material is unsupported throughout the interaction region.

18. The bulk material analyser of any one of claims 1 to 17, including lifting points at an upper section of the housing.

19. The bulk material analyser of claim 18, wherein the lifting points are provided by eye-bolts.

20. The bulk material analyser of claim 18 or 19, including a canopy for protecting the analyser, the canopy being attached to the lifting points.

21. The bulk material analyser of any one of claims 1 to 20, wherein the neutron source and detector are configured for analysis using Prompt Gamma Neutron Activation Analysis (PGNAA).

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22. The bulk material analyser of any one of claims 1 to 21, including multi-channel analyser electronics, wherein the gamma-ray detector and the multi-channel analyser electronics are located within a common air-conditioned, temperature-controlled detector enclosure.

23. The bulk material analyser of any one of claims 1 to 22, wherein the neutron source is disposed below the conveyor belt, and the gamma ray detector is disposed above the conveyor belt.

24. The bulk material analyser of any one of claims 1 to 23, wherein the analyser includes a housing that defines the enclosed tunnel.

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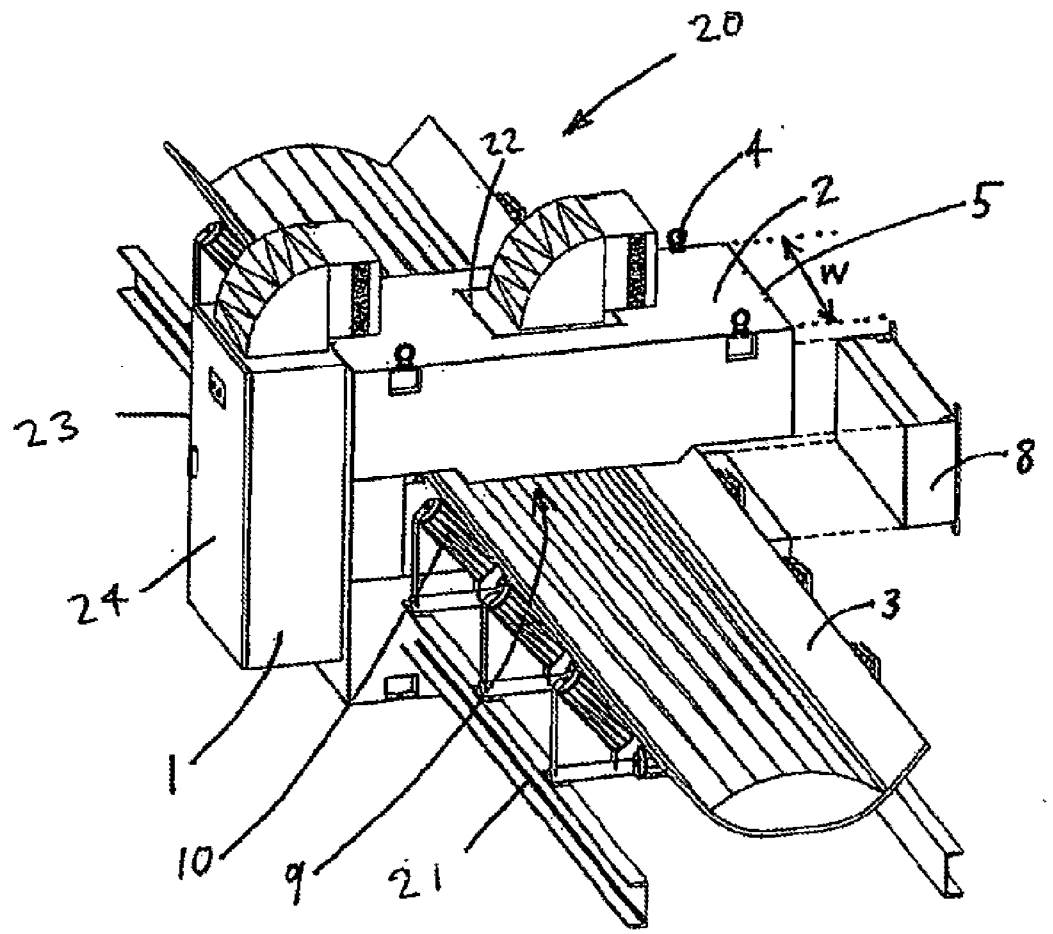

Figure 1

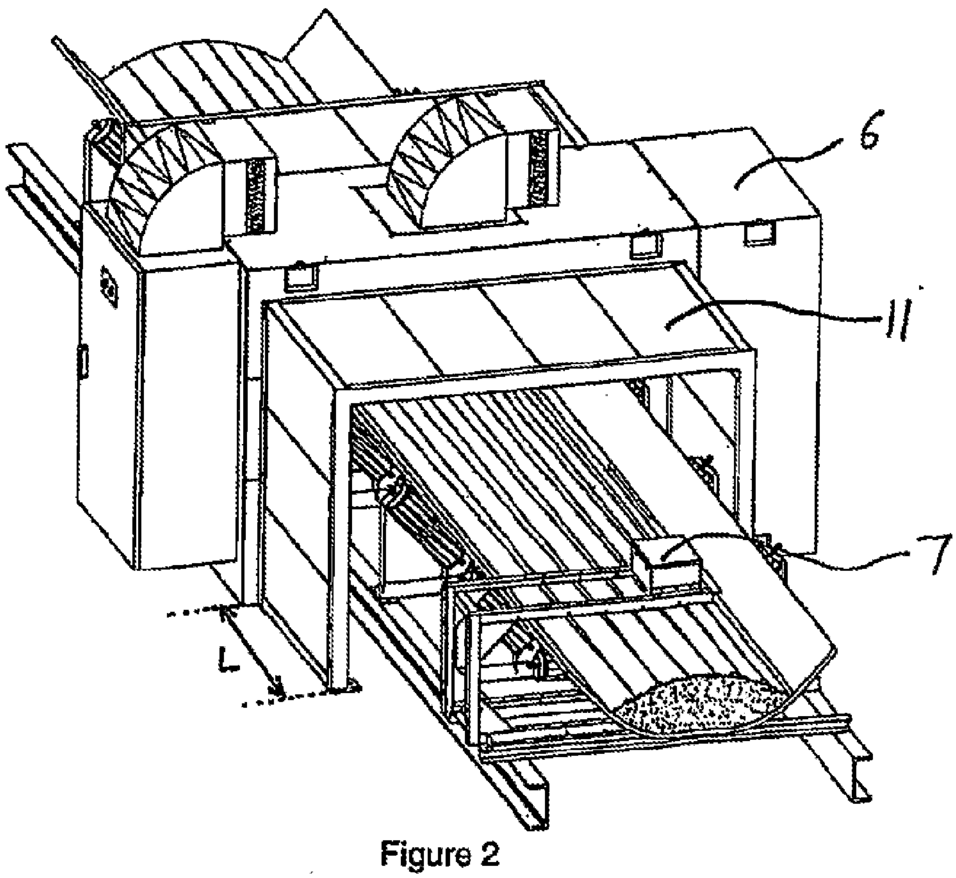

Figure 2

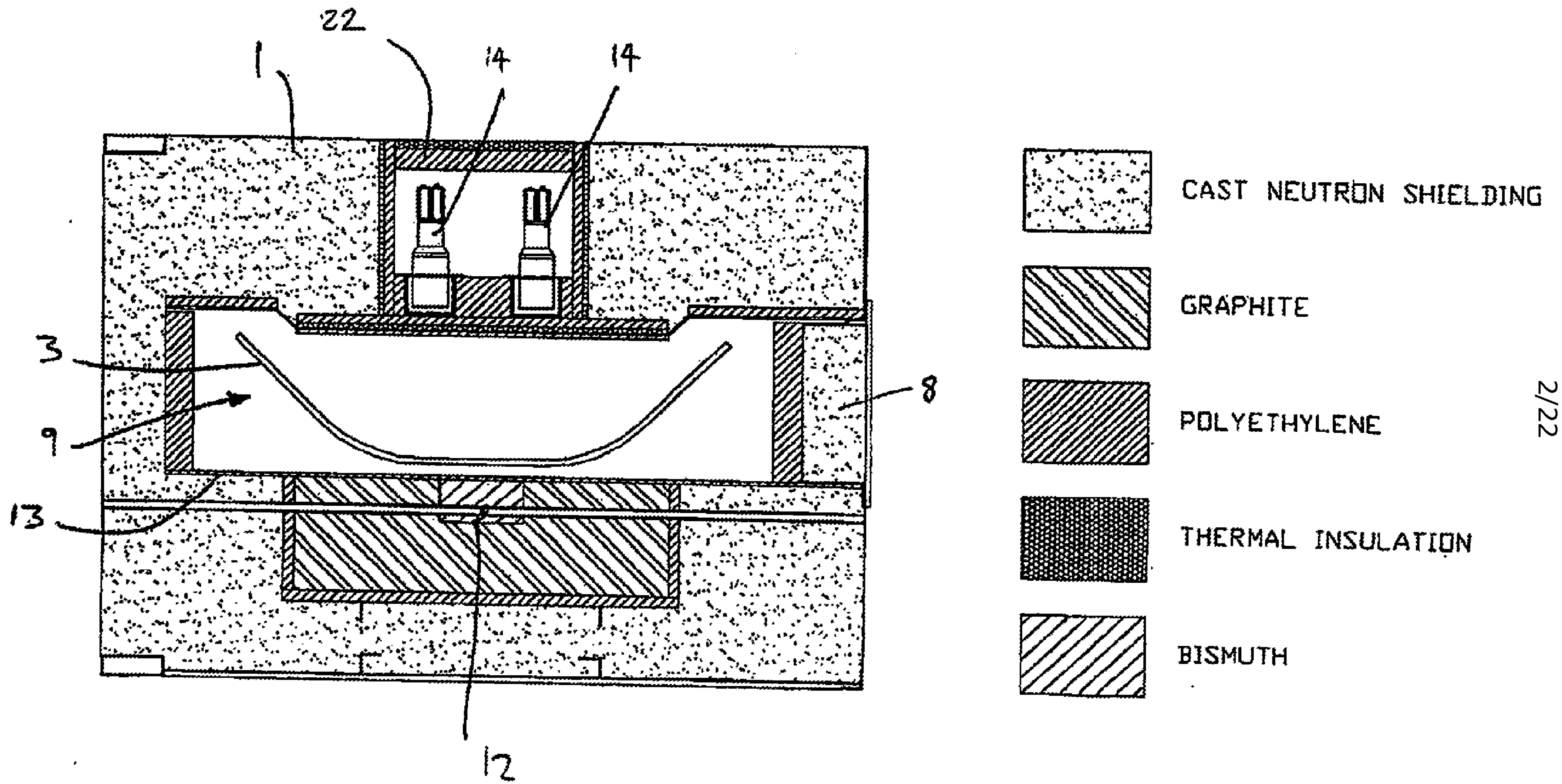
22
1
14
14
3
9
13
8
12
CAST NEUTRON SHIELDING
GRAPHITE
POLYETHYLENE
THERMAL INSULATION
BISMUTH

Figure 3

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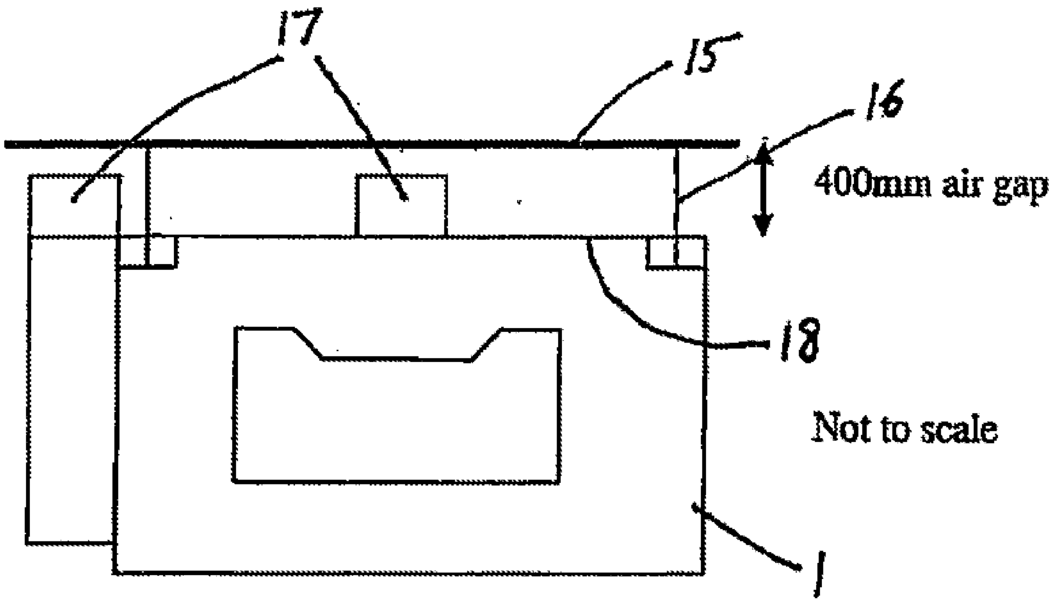

Figure 4

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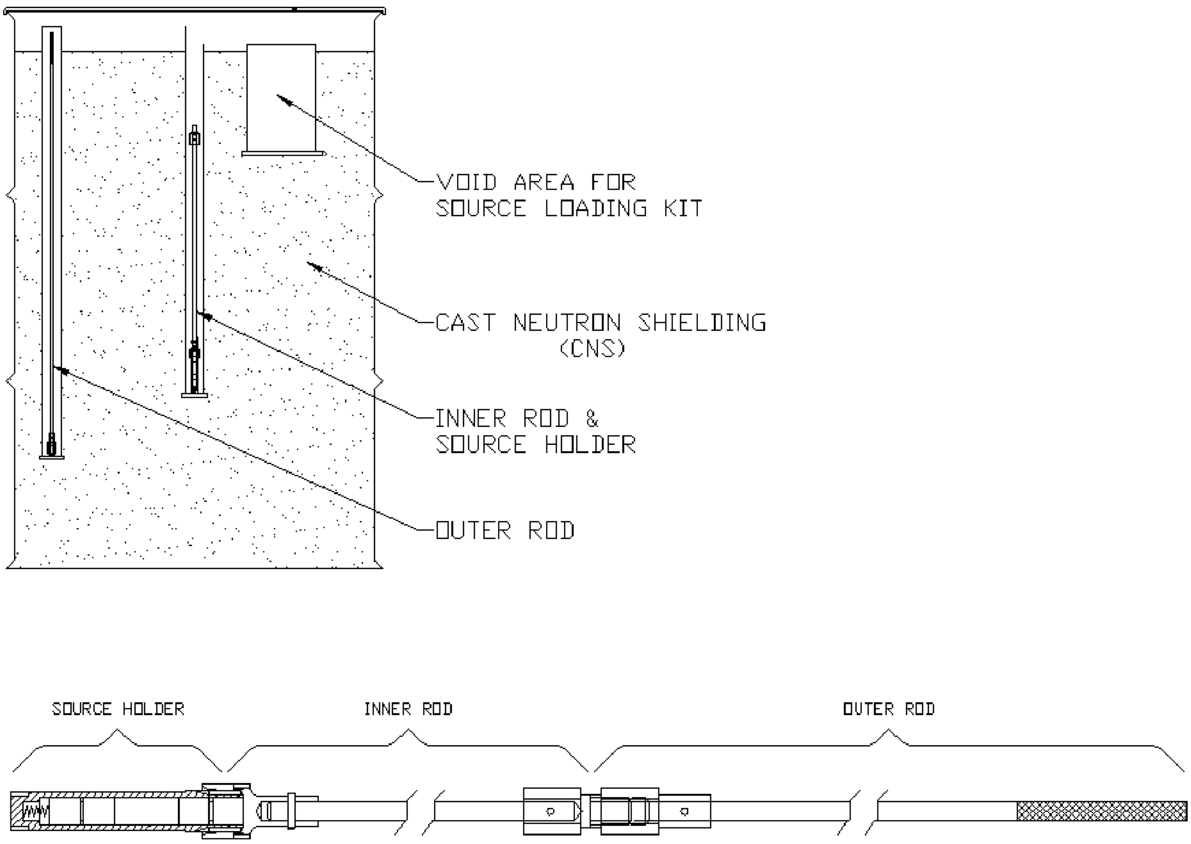

Figure 5

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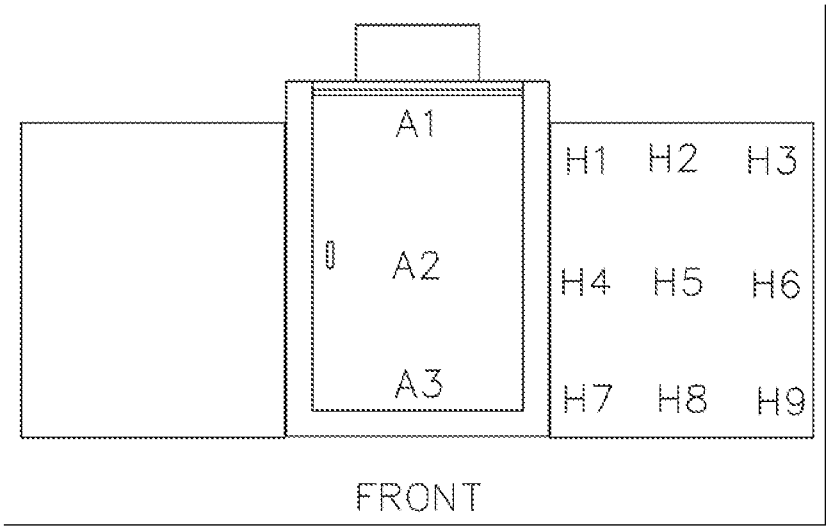

Figure 6

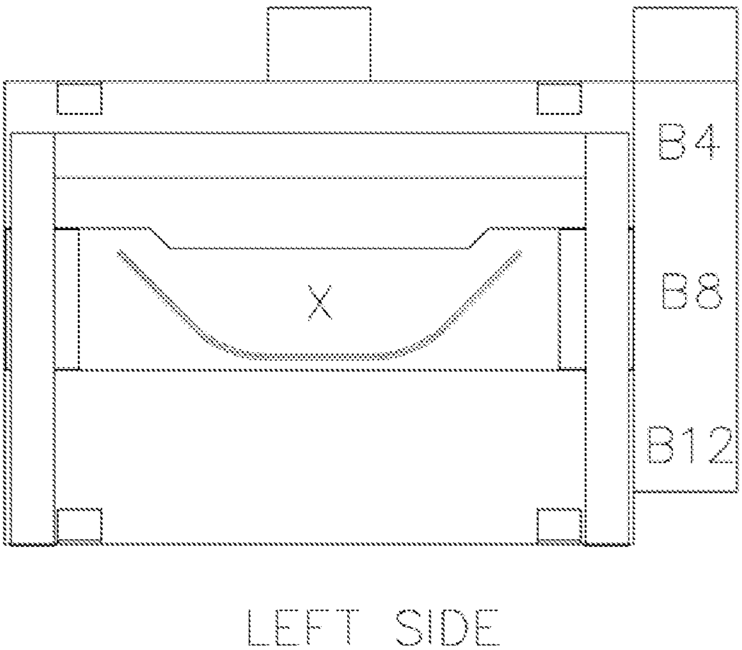

Figure 7

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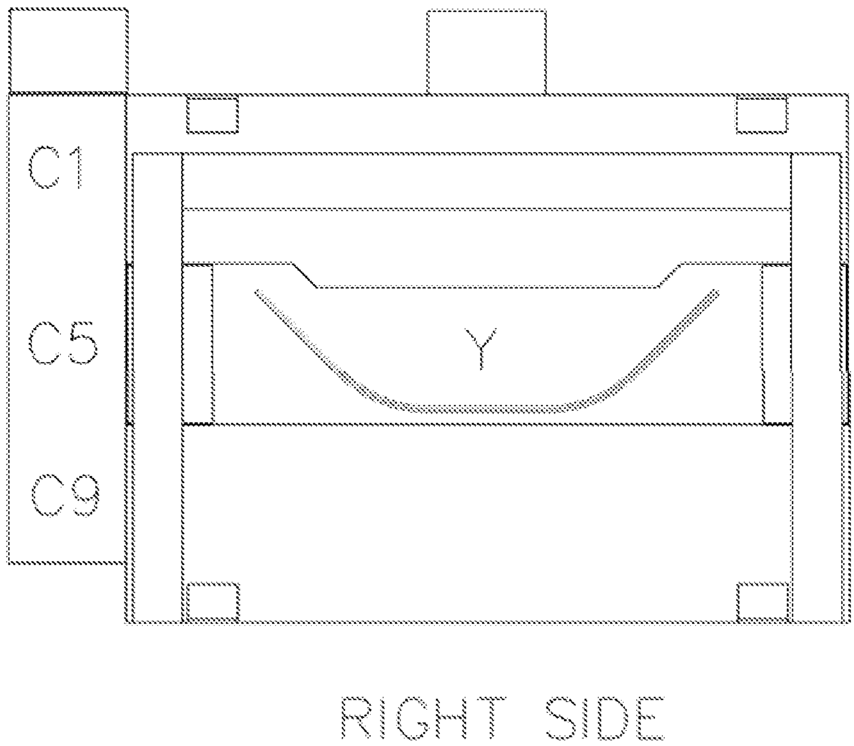


Figure 8

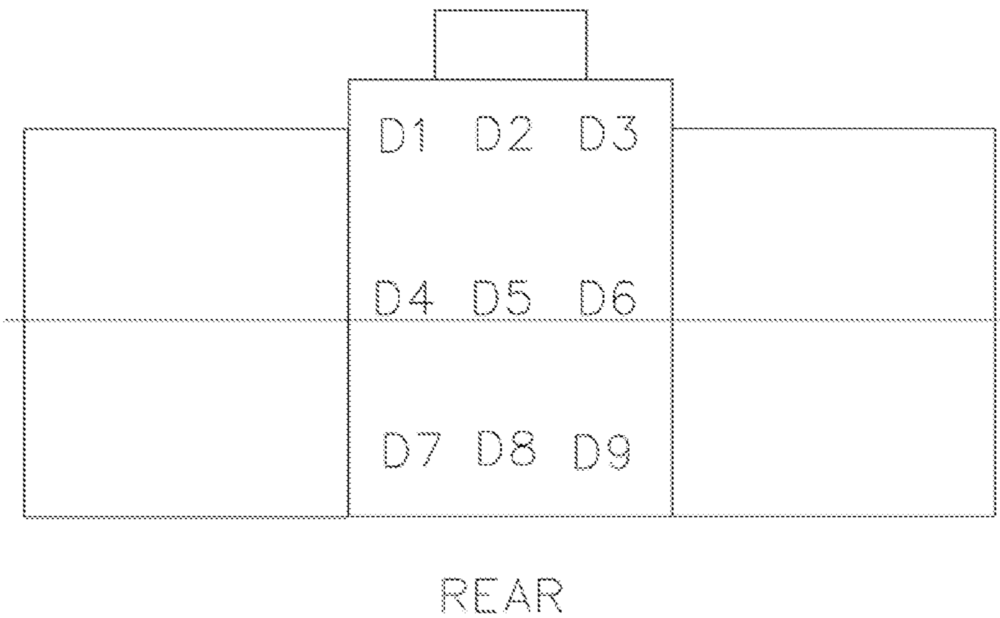
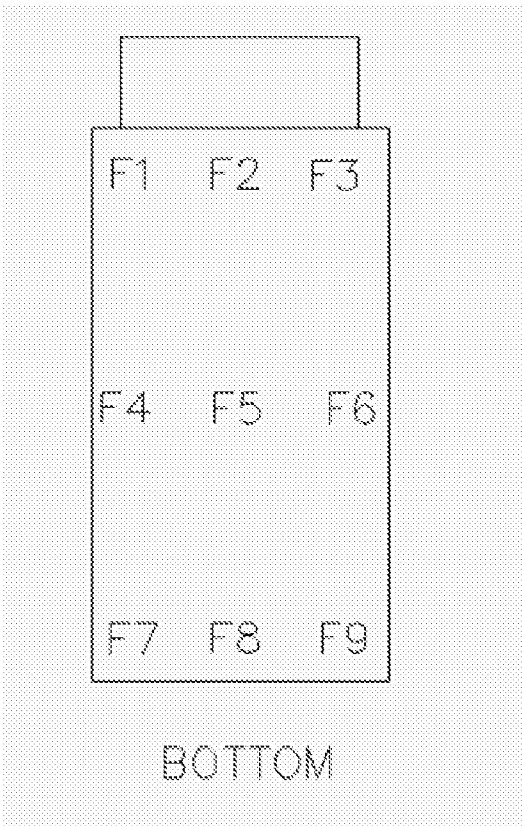


Figure 9

Figure 10



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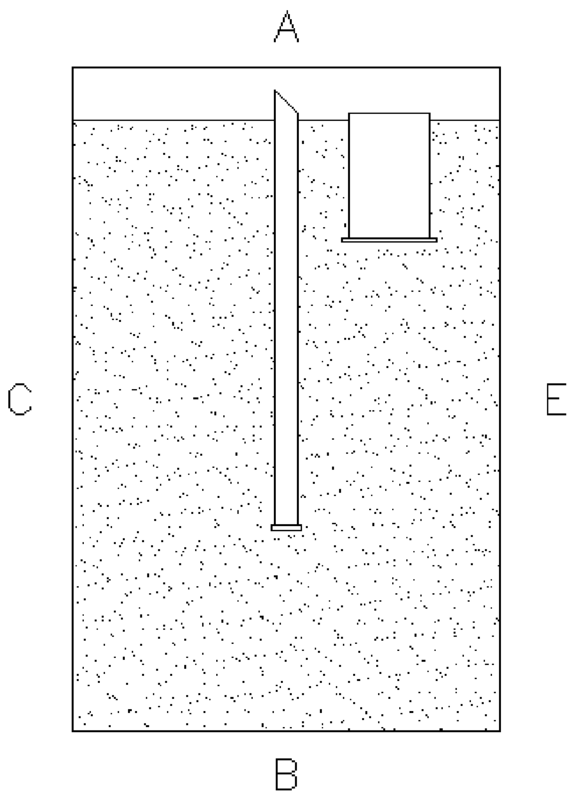

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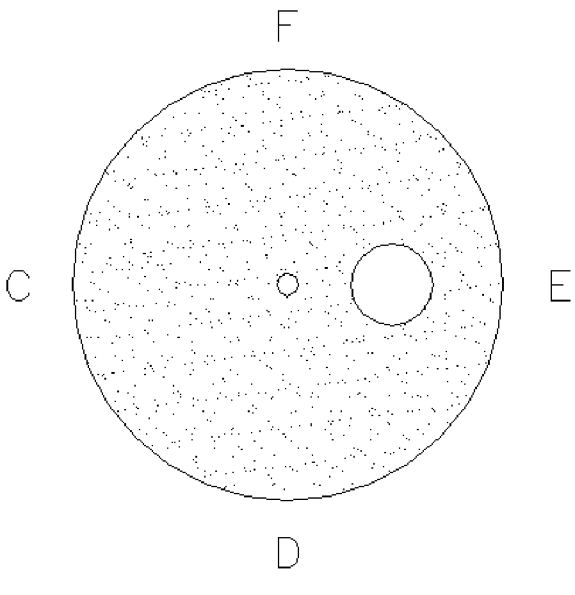

Figure 13

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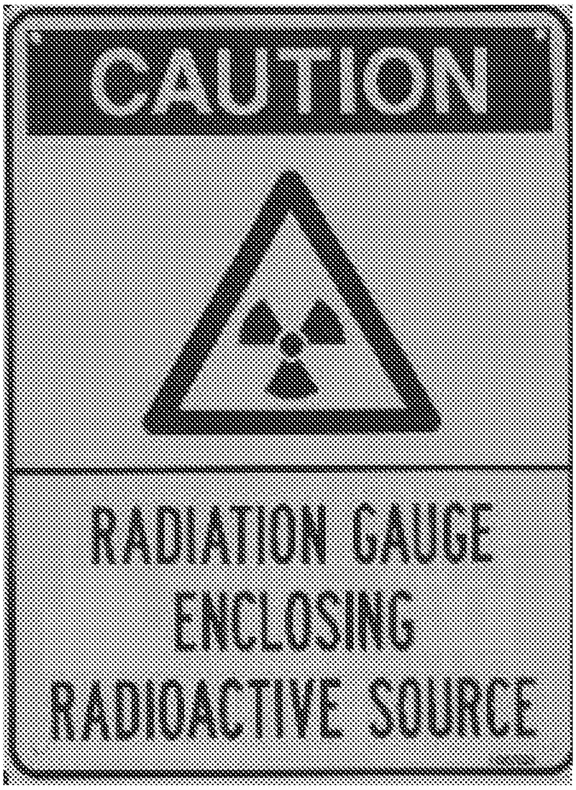

Figure 14

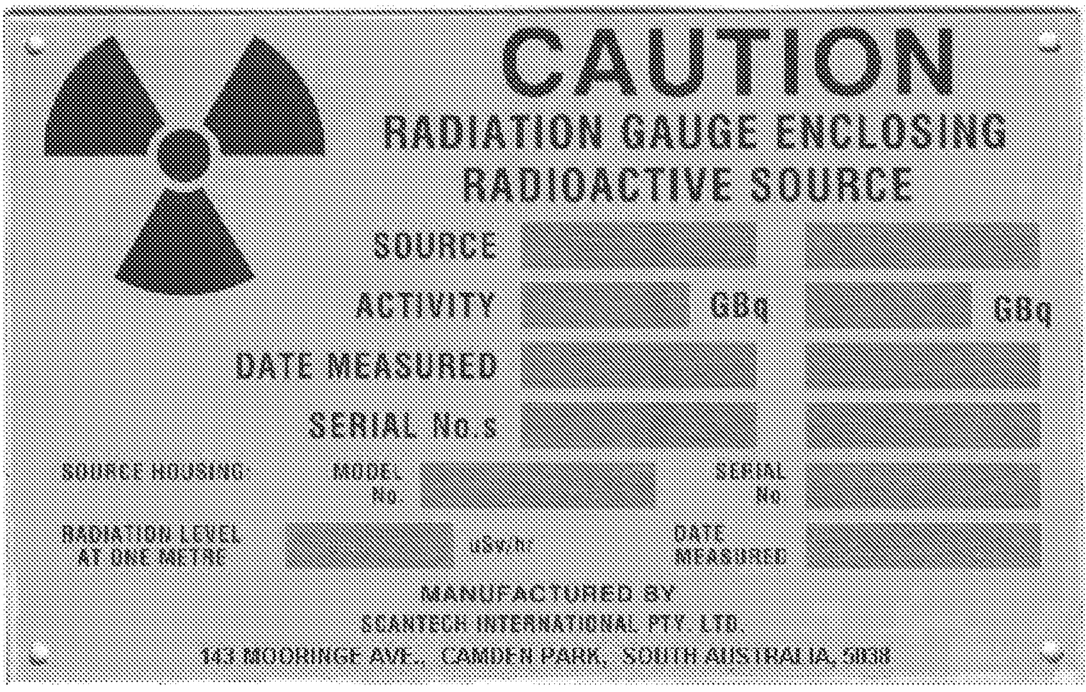

Figure 15

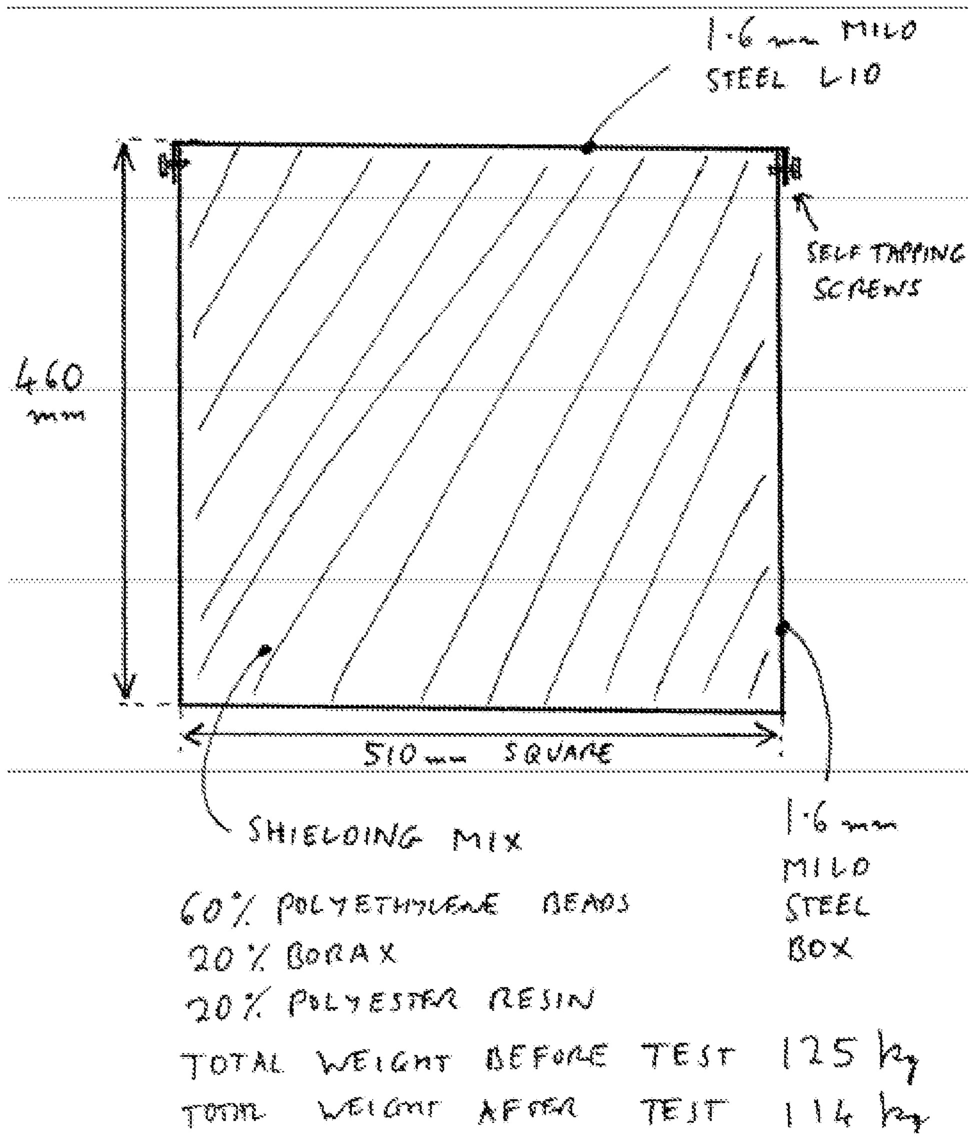
1·6 mm MILD STEEL LID
SELF TAPPING SCREWS
460 mm
510 mm SQUARE
SHIELDING MIX
1·6 mm MILD STEEL BOX
60% POLYETHYLENE BEADS
20% BORAX
20% POLYESTER RESIN
TOTAL WEIGHT BEFORE TEST 125 kg
TOTAL WEIGHT AFTER TEST 114 kg

Figure 16

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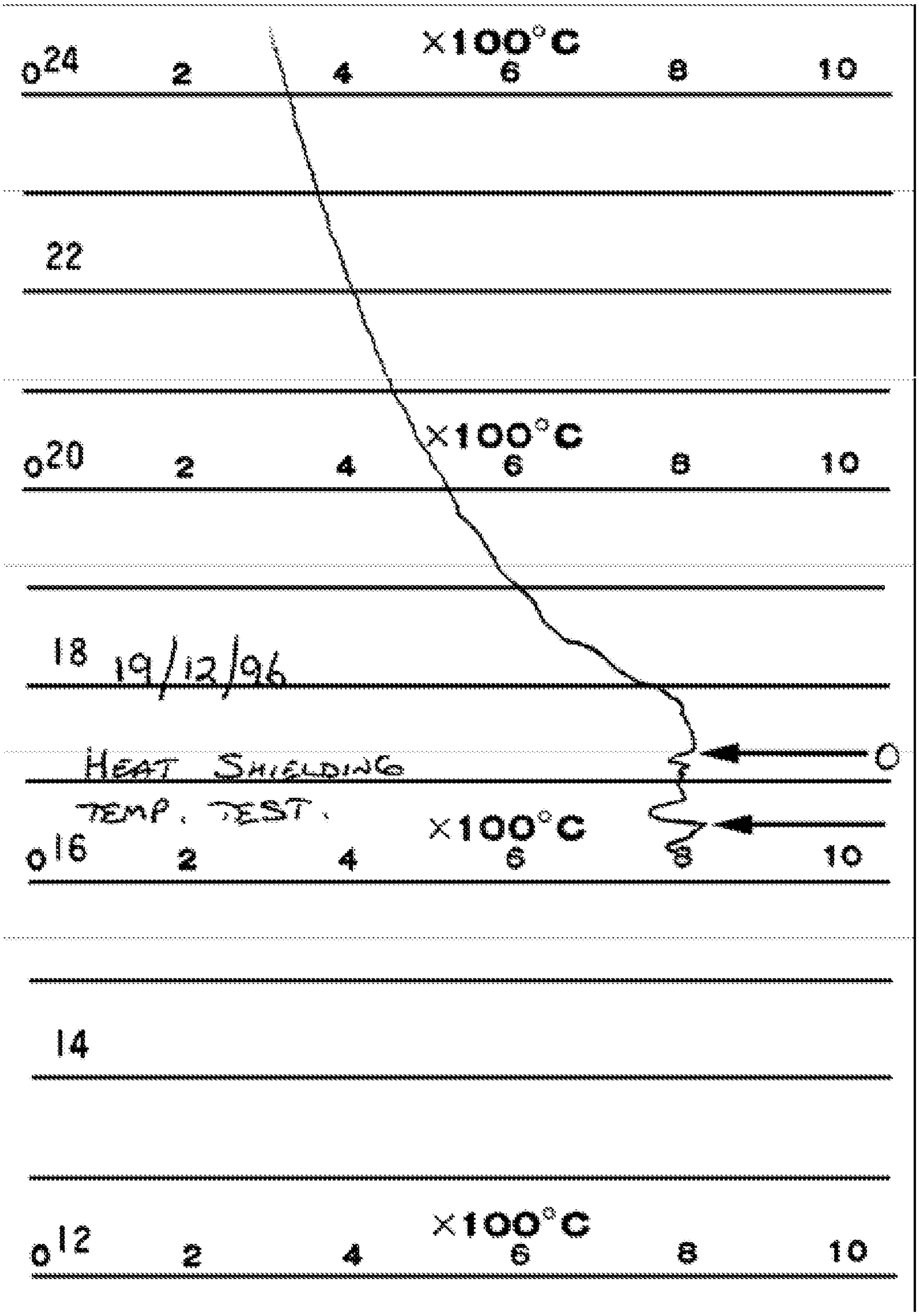

Figure 17

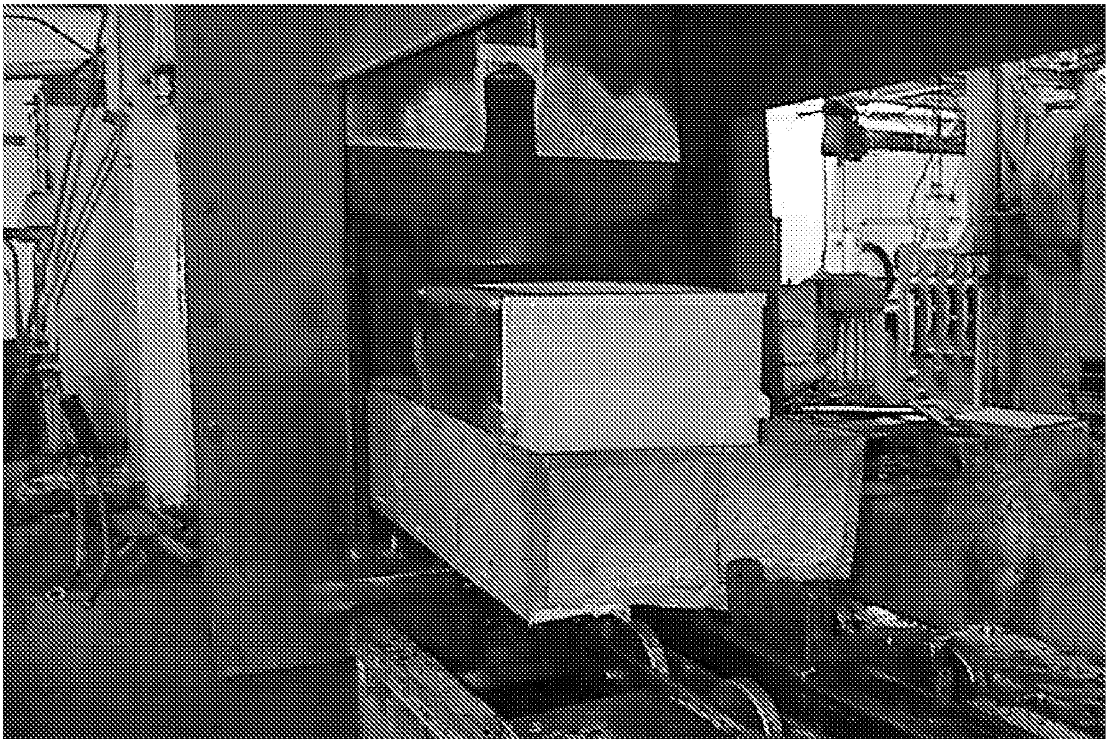

Figure 18

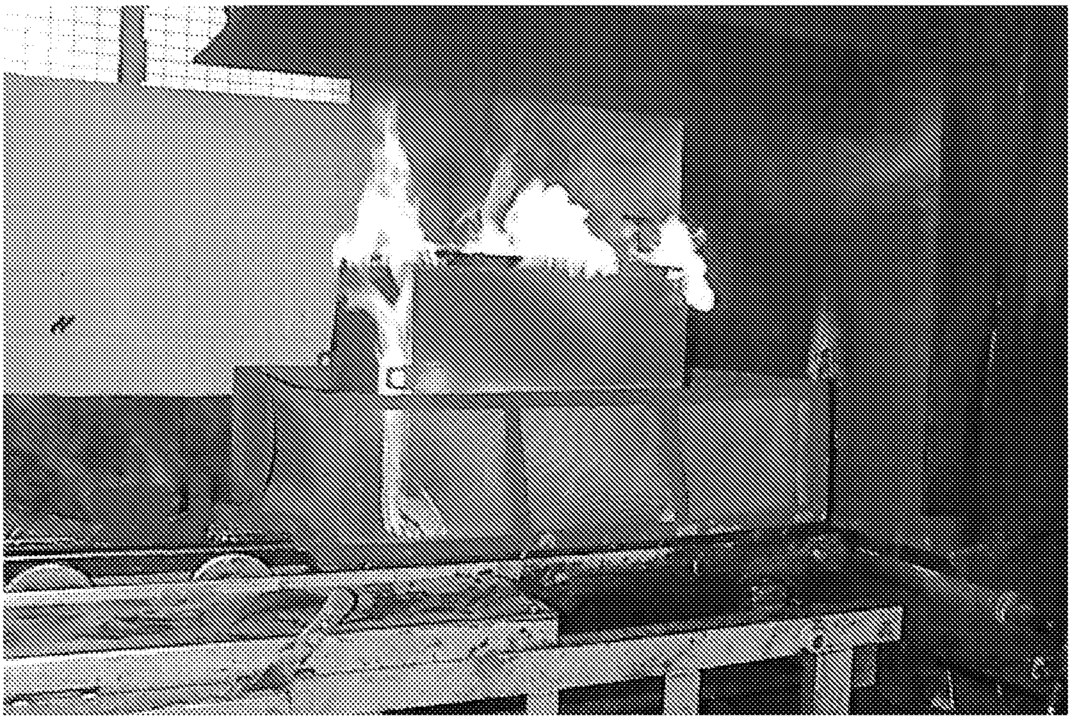

Figure 19

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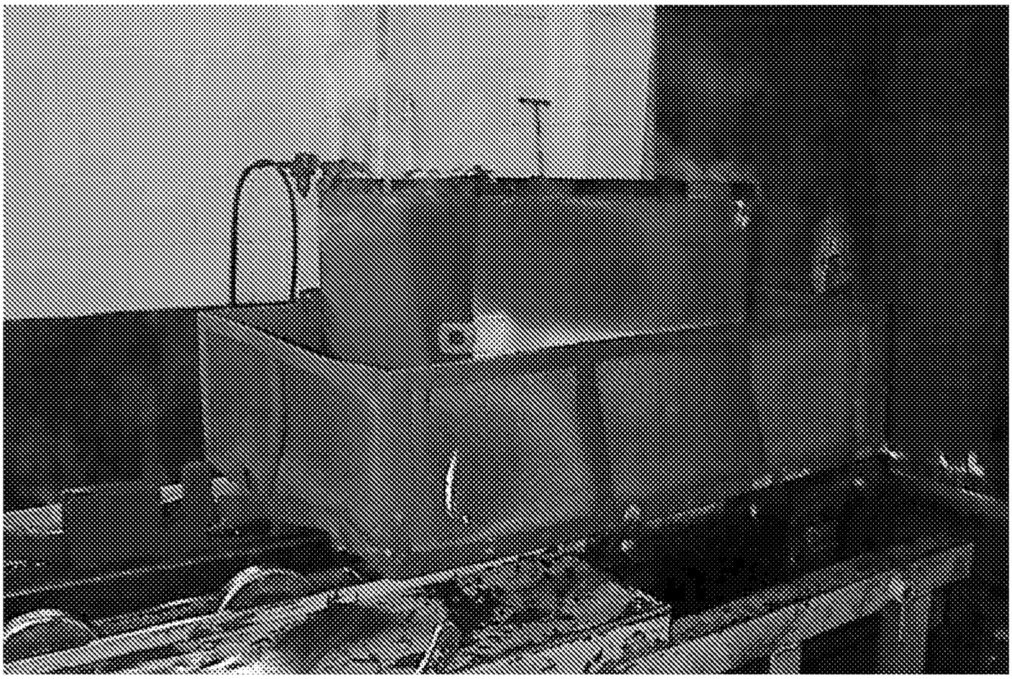

Figure 20

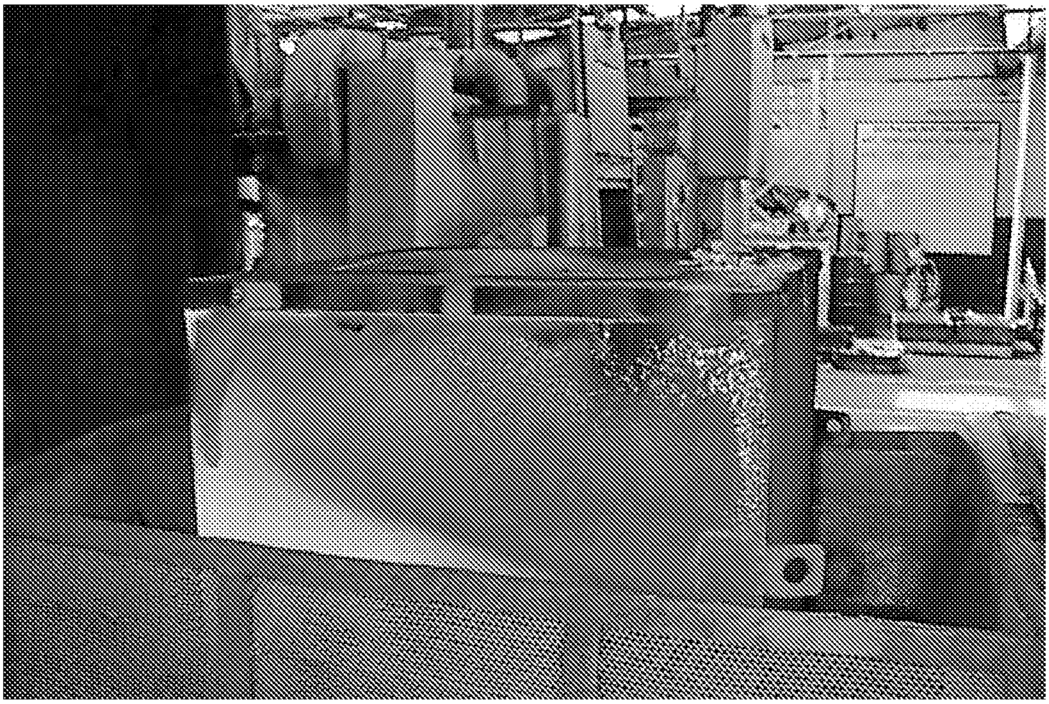

Figure 21

Figure 22

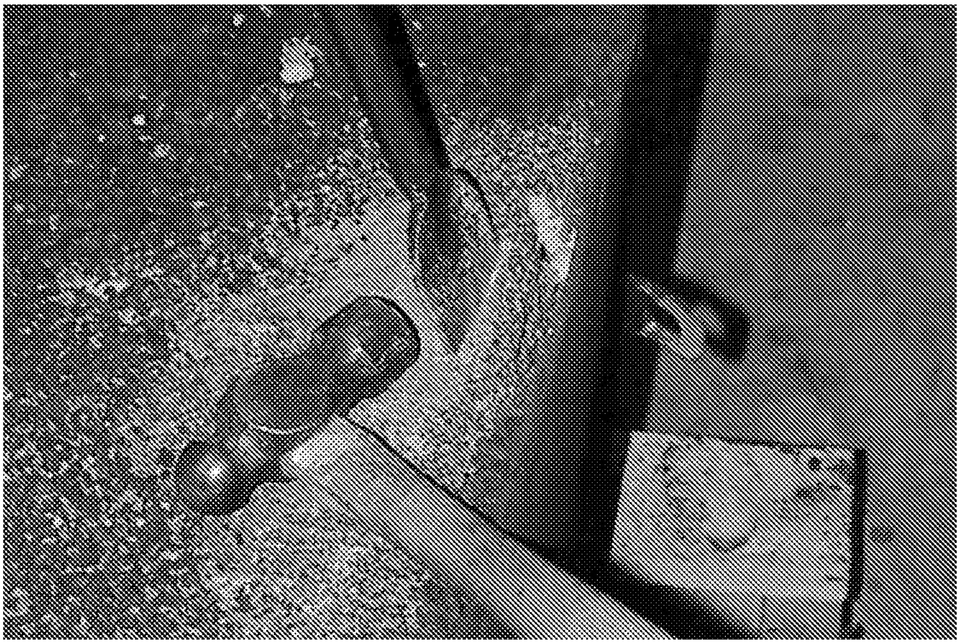

Figure 23

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Figure 24

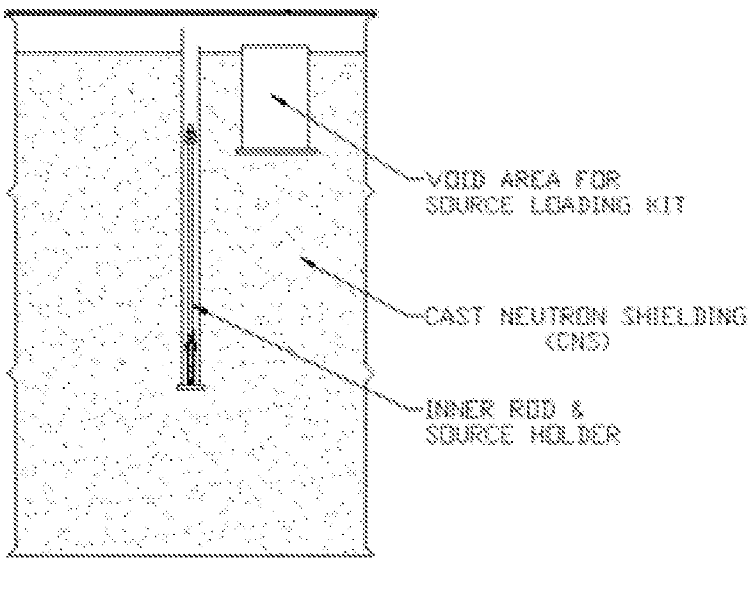

Figure 25

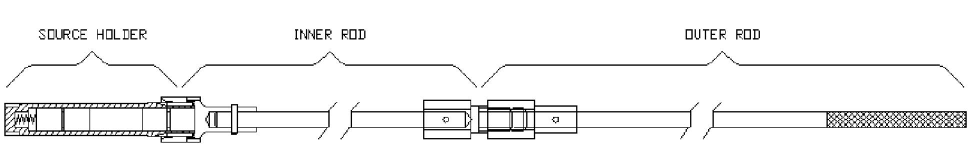

Figure 26

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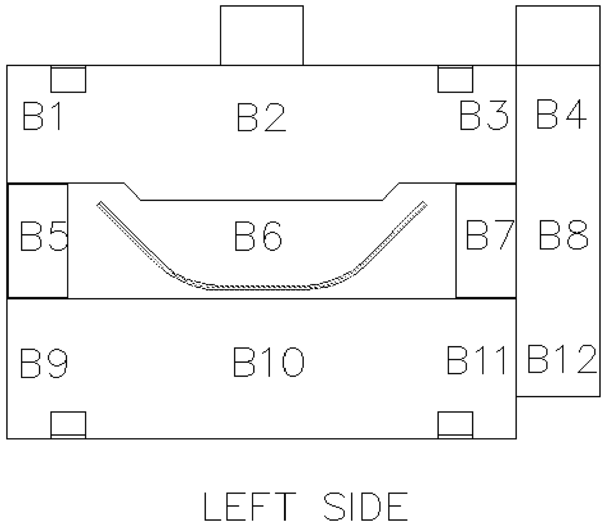

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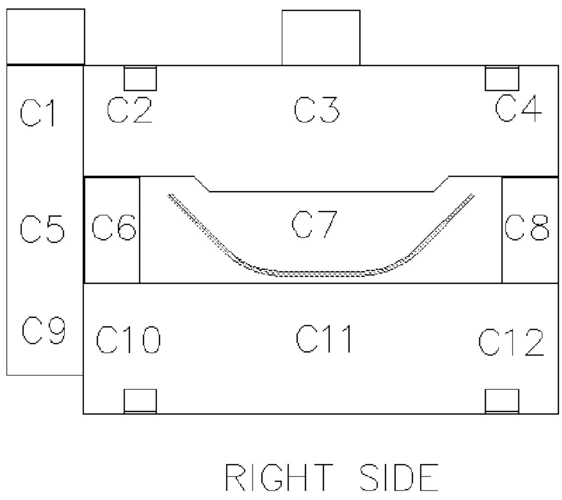
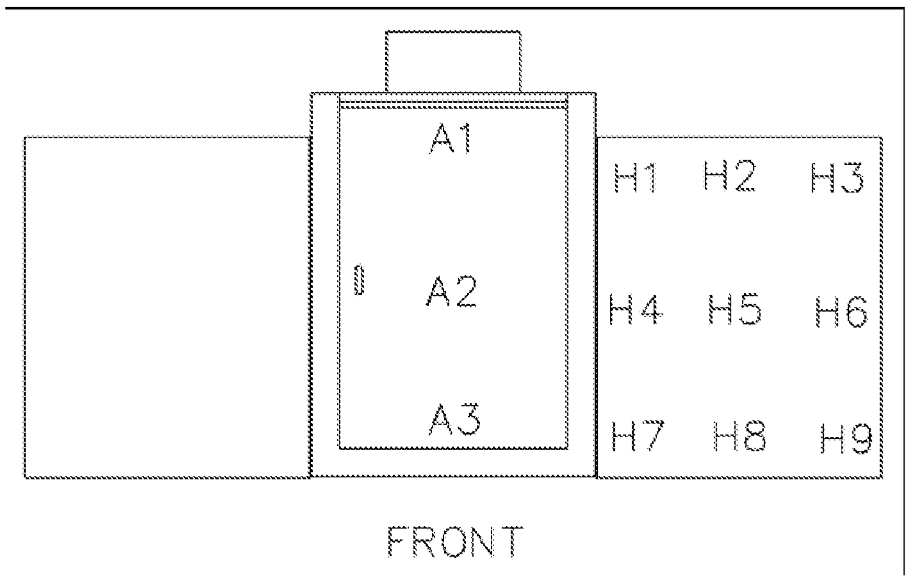


Figure 28



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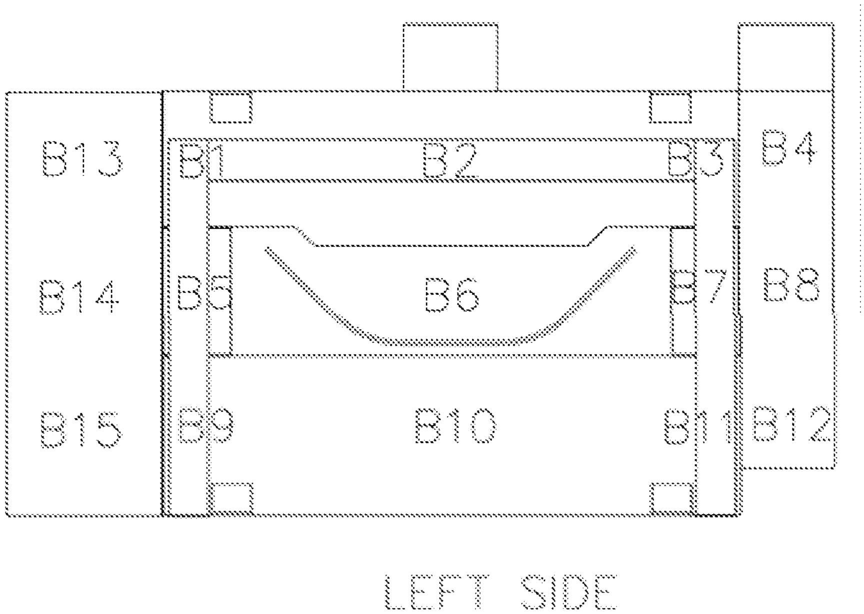

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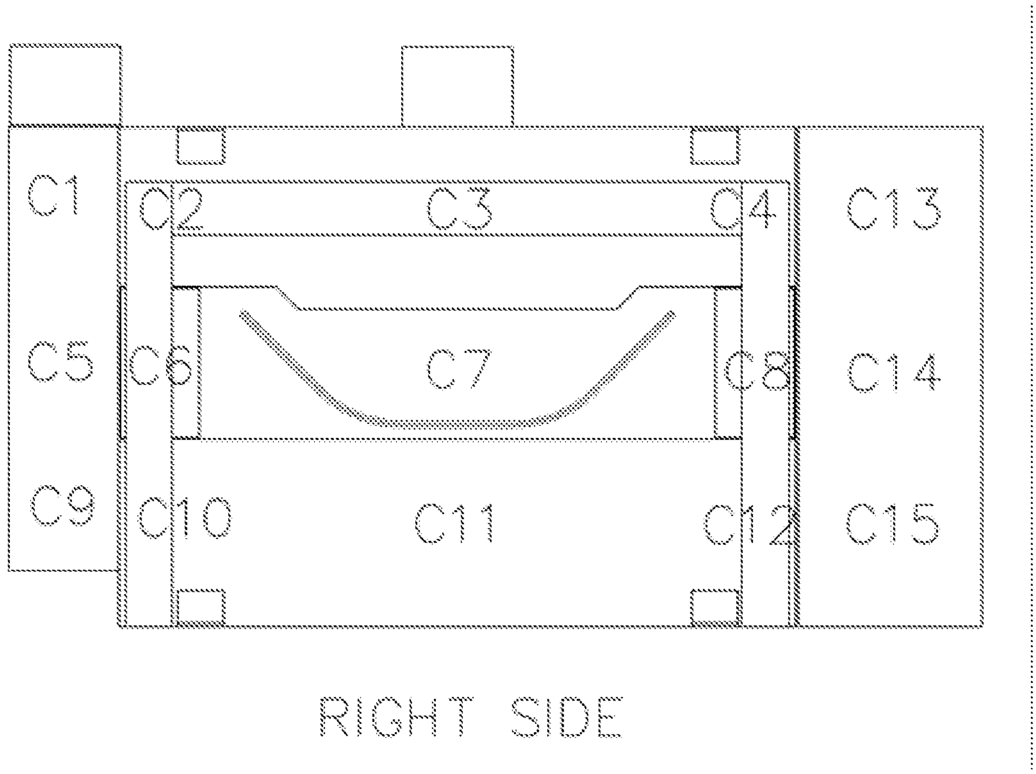

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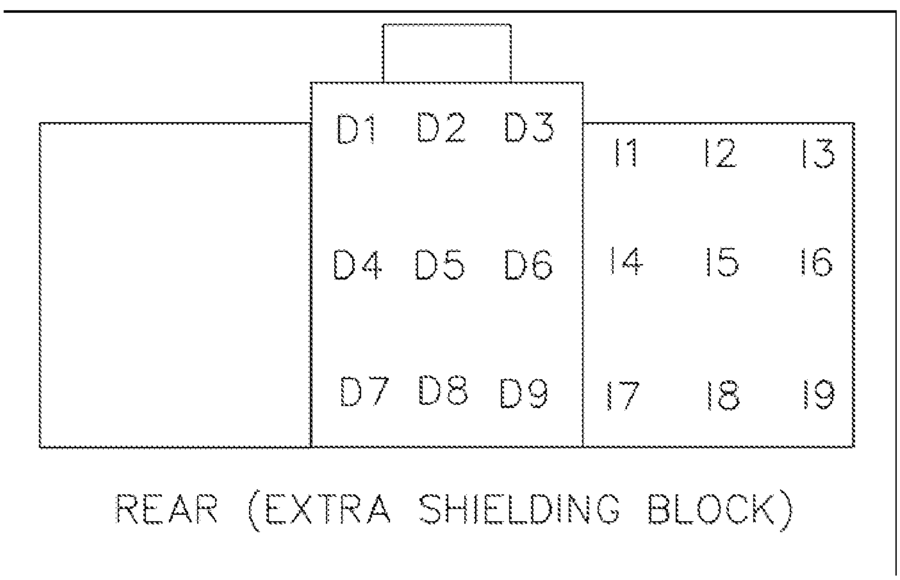

Figure 32

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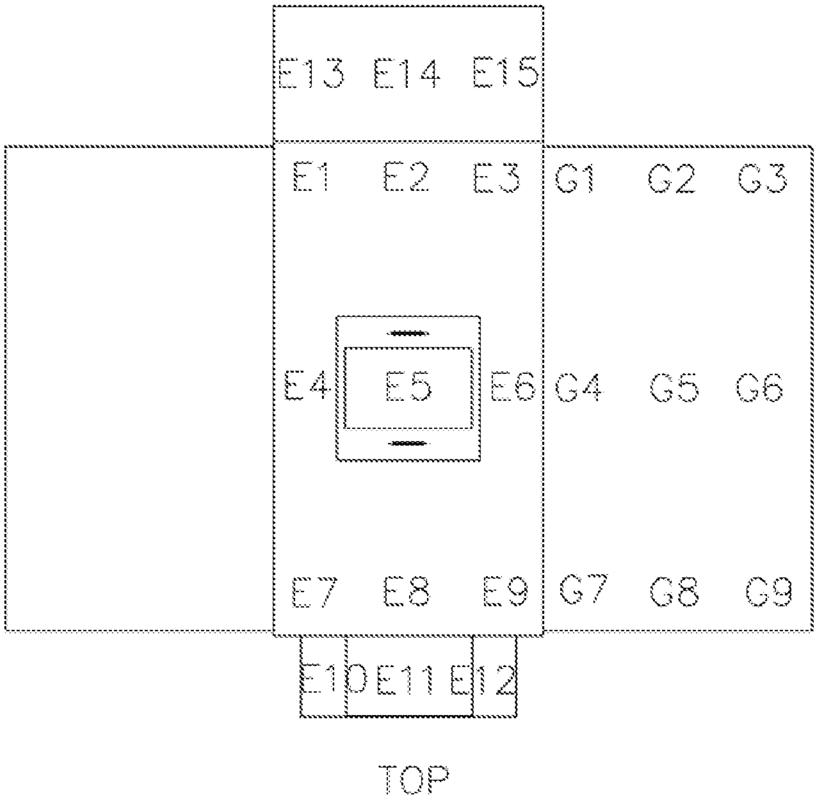

Figure 33

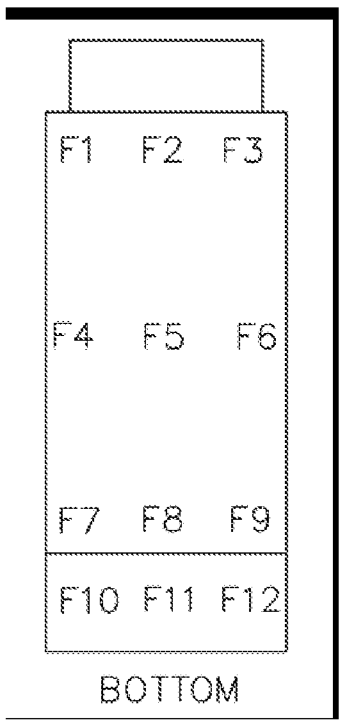

Figure 34

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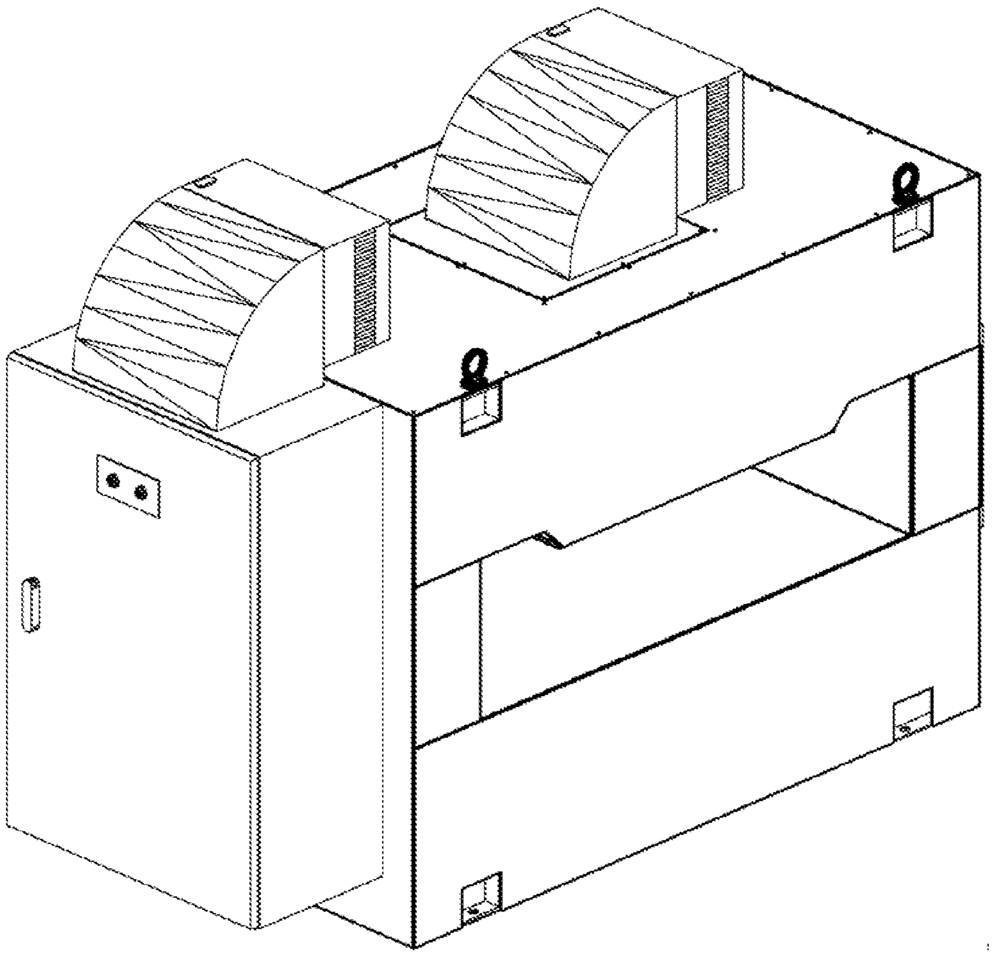

Figure 35

2016201678 20 May 2016

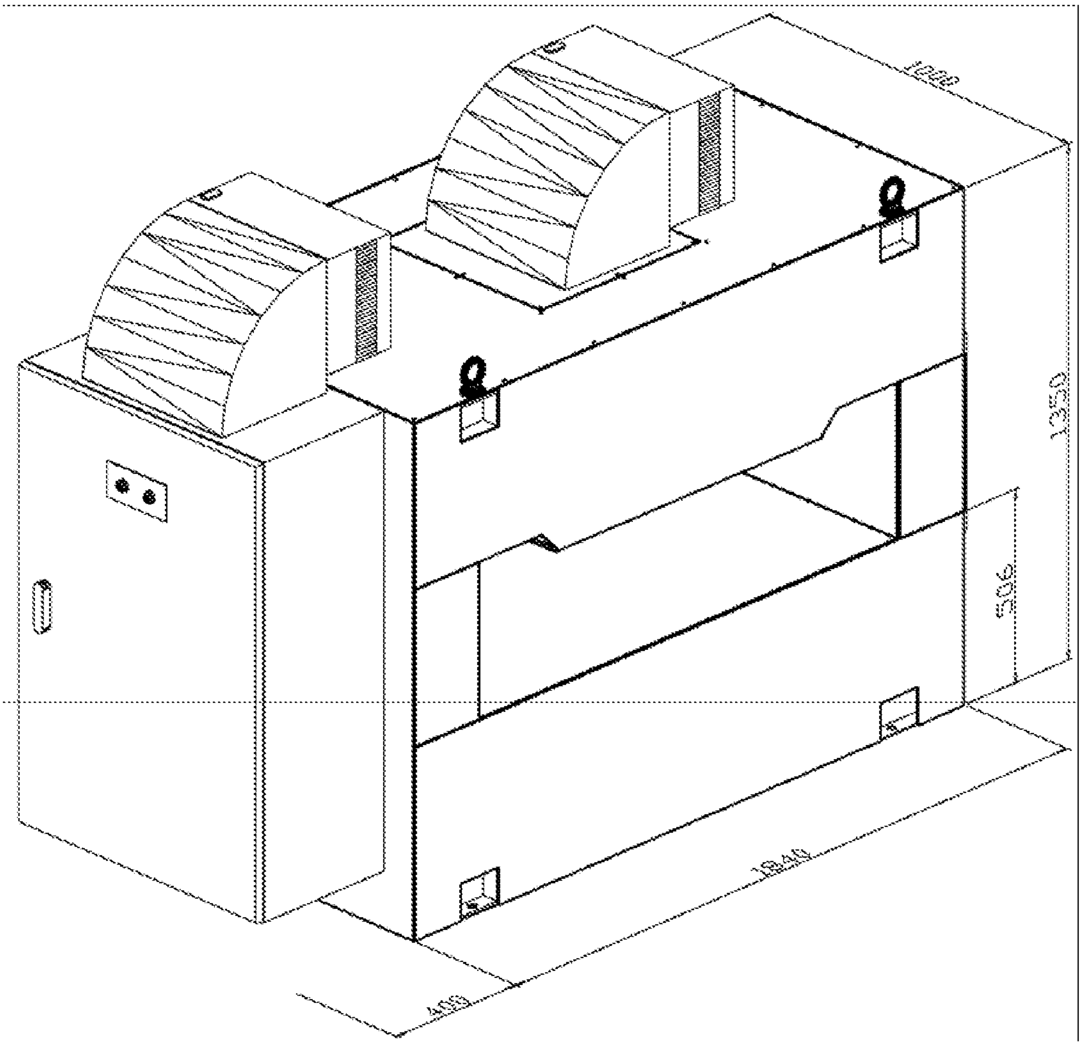

Figure 36

2016201678 20 May 2016

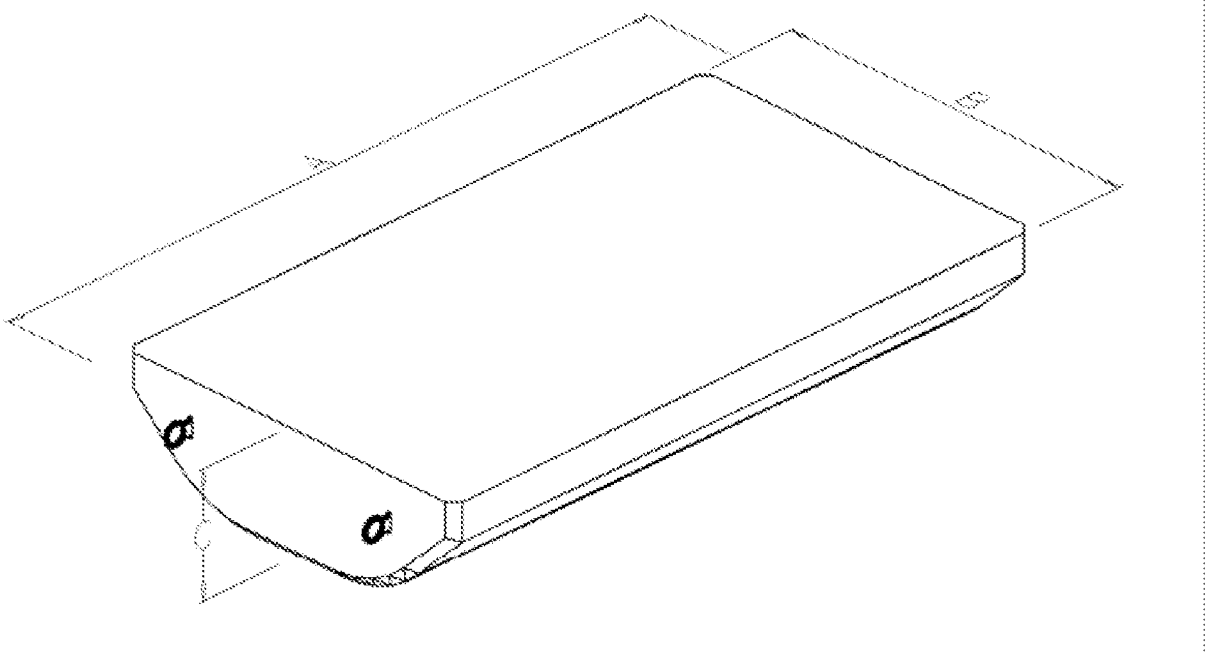

Figure 37