(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) **World Intellectual Property Organization**
International Bureau

(43) **International Publication Date**
23 September 2021 (23.09.2021)

WIPO | PCT

(10) **International Publication Number**
WO 2021/184083 A1

(51) **International Patent Classification:**
G01N 1/20 (2006.01) *G01N 21/3563* (2014.01) *G01N 15/00* (2006.01) *G01N 21/3581* (2014.01) *G01N 21/01* (2006.01) *G01N 21/359* (2014.01) *G01N 21/27* (2006.01) *G01N 21/47* (2006.01) *G01N 21/31* (2006.01) *G01N 21/55* (2014.01) *G01N 21/33* (2006.01) *G01N 21/85* (2006.01)

(21) **International Application Number:** PCT/AU2021/050257

(22) **International Filing Date:** 19 March 2021 (19.03.2021)

(25) **Filing Language:** English

(26) **Publication Language:** English

(30) **Priority Data:**
2020900858 20 March 2020 (20.03.2020) AU

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(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, IT, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD,

(54) **Title:** SYSTEMS AND METHODS FOR IN-LINE SAMPLING OF PARTICULATE MATTER

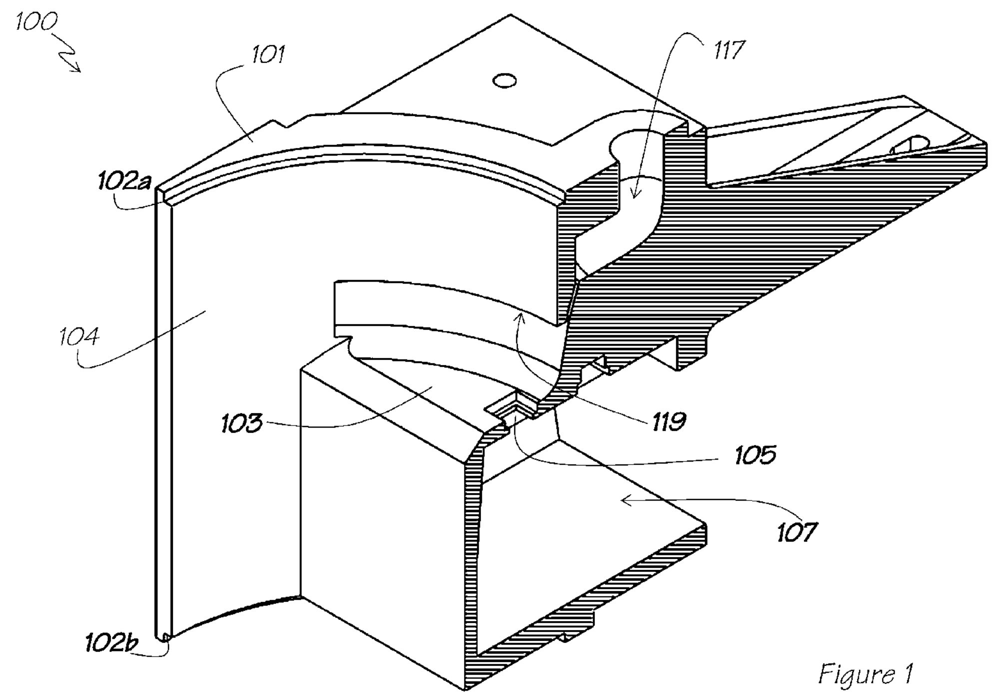

Figure 1

(57) **Abstract:** A system for in-line sampling of particulate matter, comprising: a frame adapted to sealingly engage with a particulate matter transport pipe, the frame comprising: a sample ledge adapted to protrude into the pipe to receive and accumulate particulate matter flowing through the pipe; a housing adapted to receive a sampling device; an inspection window located within, or adjacent to, the sample ledge; a gas inlet port adapted to receive and transport a jet of gas; a gas outlet port adapted to direct the jet of gas to flow across the sample ledge so as to clear accumulated particulate matter from the sample ledge. Also, a method for in-line sampling of particulate matter in a particulate matter flow transport pipe; and a kit for a system for in-line sampling of particulate matter.

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[Continued on next page]

ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

SYSTEMS AND METHODS FOR IN-LINE SAMPLING OF PARTICULATE MATTER

Field of the Invention

[0001] The present invention relates to systems and method for particle sampling and in particular to systems and methods for sampling and analysis of particulate matter.

[0002] The invention has been developed primarily for use in methods and systems for real-time or near-real-time in-line sampling and analysis of particulate matter flowing through a particle transport pipe and will be described hereinafter with reference to this application. However, it will be appreciated that the invention is not limited to this particular field of use.

Background

[0003] Any discussion of the background art throughout the specification should in no way be considered as an admission that such background art is prior art, nor that such background art is widely known or forms part of the common general knowledge in the field in Australia or worldwide.

[0004] All references, including any patents or patent applications, cited in this specification are hereby incorporated by reference. No admission is made that any reference constitutes prior art. The discussion of the references states what their authors assert, and the applicants reserve the right to challenge the accuracy and pertinence of the cited documents. It will be clearly understood that, although a number of prior art publications are referred to herein, this reference does not constitute an admission that any of these documents' forms part of the common general knowledge in the art, in Australia or in any other country.

[0005] In a flour or feed mill, grain, or other materials are ground to form fine, dry, particulate matter. Once ground the particles are moved in pipes pneumatically in an air flow or using gravity. Regular and accurate sampling of the particulate matter is crucial to the operation of the mill and ensure a quality product. Quality control testing of the particulate matter is only as good as the tested sample, so the process for obtaining a true representative sample of the particles in any particular pipe throughout the mill, which can accurately measure the characteristics of the whole batch or lot travelling through the tested pipe is critical.

[0006] In the case of a flour mill the dry particles may be sorted into different portions or fractions based on particle size and density. The number of portions which the dry particles are separated into will vary from operation to operation but is typically between 10 to 20 different portions. These separated portions are moved through the mill via pipes to different processing operations. Different portions of the batch typically have different properties including colour and chemical composition. The particles flowing in different pipes may subsequently be blended in varying ratios with the particles in other pipes to meet product specifications for specified attributes. Determining the quality and particular attributes of the particulate matter flowing through each pipe can also be used to identify processing issues, which include, but are not limited to, excessive grinding, insufficient grinding or faults in the sifting process.

[0007] To manage the processing of the dry materials, including blending and further processing, it is of value to understand the characteristics of each separated portion during the different stages of processing. Samples of each portion may be taken from the pipes from time to time for next-to-line or laboratory testing. In either case the ability to make processing changes to modify stream composition is time delayed and in cases of high throughput, may result in production which is out of specification.

[0008] The flow rate in each pipe can vary significantly with some pipes consistently carrying heavy flow rates with high optical density and other pipes carrying low flow rates with low levels of optical density. At any point in time during the process, the particulate flow rate in any one pipe may change as a result of adjustments to process settings or raw material differences.

[0009] A better option than next-to-line monitoring is to provide inline measurement in multiple streams across the process. This may include monitoring multiple pipes within a single milling operation. This may be to measure attributes including but not limited to: colour, moisture, protein, ash, starch damage or oil content. When the flow rate of the particles does not create adequate optical density to measure reflected light with a suitable signal to noise ratio, it is necessary under currently available procedures to extract a static sample of the particulate matter in the pipe for manual testing (either "next-to-line" or laboratory testing). As will be appreciated, the extraction of samples from the pipe for measurement is complex and slow and thus is not able to provide real-time measurement of particulate attributes.

[0010] For systems with high flow throughput rates, it is possible to achieve adequate optical density, from the continuous flow of material, to measure reflected light with a suitable signal to noise ratio. There are systems available for such measurement which include installing one or more inspection windows into the pipe and irradiating the particles flowing through the pipe with an optical source such as a laser or lamp across the flow of the particles e.g. perpendicular to the flow direction. Light which is then reflected from the particles and/or transmitted through the pipe is detected for further analysis of the characteristics of the particles in the pipe. At present the commercially available optical systems designed for high flow rates are expensive and require high levels of illumination requiring management of heat which can damage and/or alter the characteristics of the particles under test and typically delivering these solutions at high cost.

[0011] Alternative systems that can be used to achieve a static sample, have used a bypass approach where a sample or a portion of the sample is diverted from the flow into a sample collection tube. The material accumulates in the sampling tube to establish a static sample of adequate optical density to make a measurement of reflected and/or transmitted light. The bypass system can be difficult to fit and operate. The sampling tubes often experience issues with cleaning as dry particles in a small diameter pipe typically become stuck due to surface friction between the particles and the wall of the pipe. This makes cleaning the pipes and maintenance of flow through the bypass path a significant draw back. Any moving parts associated with bypass tubes are problematic as the fine particles tend to interfere with these mechanisms.

[0012] The preferred option is to measure the dry particulate material in the pipe without a separate sampling tube or the need for sample diversion. The difficulty with measuring in the flow within the pipe is to avoid disruption of the flow and to adjust the pipe throughput in real-time to situations where the flow does not provide adequate optical density.

[0013] Therefore, there is a significant need to be able to take inline measurements across multiple pipes each with variable flow rates.

Summary

[0014] It is an object of the present invention to overcome or ameliorate at least one or more of the disadvantages of the prior art, or to provide a useful alternative.

[0015] The key challenge of measuring particulate characteristics flowing through a pipe is to do so interfering with the particulate material flow and to manage optical measurements when there is low flow rates that do not allow adequate optical density to measure the continuous stream of the particulate matter in the pipe.

[0016] According to a first aspect of the present invention, there is provided a system for in-line sampling of particulate matter. The system may comprise a frame adapted to sealingly engage with a particulate matter transport pipe. The frame may comprise a sample ledge adapted to protrude into the pipe to receive and accumulate particulate matter flowing through the pipe. The system may further comprise a housing adapted to receive a sampling device. The system may further comprise an inspection window located within, or adjacent to, the sample ledge. The system may further comprise a gas inlet port adapted to receive and transport a jet of gas. The system may further comprise a gas outlet port adapted to direct the jet of gas to flow across the sample ledge so as to clear accumulated particulate matter from the sample ledge.

[0017] According to a particular arrangement of the first aspect, there is provided a system for in-line sampling of particulate matter, comprising:

a frame adapted to sealingly engage with a particulate matter transport pipe, the frame comprising:

a sample ledge adapted to protrude into the pipe to receive and accumulate particulate matter flowing through the pipe;

a housing adapted to receive a sampling device;

an inspection window located within, or adjacent to the sample ledge such ;

a gas inlet port adapted to receive and transport a jet of gas; and

a gas outlet port adapted to direct the jet of gas to flow across the sample ledge so as to clear accumulated particulate matter from the sample ledge.

[0018] The system may further comprise an optical source for emitting optical radiation through the inspection window. The optical source may be adapted to illuminate particulate matter accumulated on the sample ledge.

[0019] The system may further comprise an optical detector adapted to detect optical radiation reflected from the accumulated particulate matter through the inspection window.

[0020] The optical source may be a narrow linewidth optical source; or a broadband optical source. The optical source may be a near-infrared optical source; a visible optical source; a far-infrared optical source; or an ultraviolet optical source. The optical source may be a tunable optical source.

[0021] The system may further comprise a comprise a processor and memory, wherein the processor is configured for: controlling the optical source; receiving and analysing optical signals detected by the detector; and initiating a jet of gas to clear accumulated particulate matter from the sample ledge. The processor may be configured to execute program instructions for:

irradiating particulate matter accumulated on the sample ledge with optical radiation generated by the optical source;

monitoring reflected optical radiation from accumulated particulate matter on the sample ledge to determine the optical density of the accumulated particulate matter;

determining when the optical density of the accumulated particulate matter is the equivalent of infinite optical density;

measuring one or more attributes of the accumulated particulate matter from the reflected optical radiation received by the optical detector; and

activating a jet of gas to be directed from the gas outlet port across the sample ledge to clear the accumulated particulate matter from the sample ledge.

[0022] The frame may comprise upper and lower sealing lips adapted to engage with a wall of the pipe thereby to seal the pipe when the frame is installed therein.

[0023] The inspection window may comprise an optically transparent inspection window adapted to permit optical inspection using the sampling device of particulate matter accumulated on the sample ledge.

[0024] The gas inlet port may be connected to a compressed gas source. The gas may be an inert gas. The gas may be air. The compressed gas may have a pressure of between about 100 kPa to about 1000kPa. The compressed gas may have a pressure of between about 200 kPa to about 800k Pa. The compressed gas may have a pressure of about 100 kPa, 150 kPa, 200 kPa, 250 kPa, 300 kPa, 350 kPa, 400 kPa, 450 kPa, 500 kPa, 550 kPa, 600 kPa, 650 kPa, 700 kPa, 750 kPa, 800 kPa, 850 kPa, 900 kPa, 950 kPa, or about 1000 kPa.

[0025] The frame may be installed in a pipe with a slope angle of between about 0° to about 80° to the vertical. The frame may be installed in a pipe with a slope angle of between about 0° to about 80° to the vertical, or about 5° to about 75°, about 10° to about 70°, about 15° to about 65°, about 20° to about 60°, about 25° to about 55°, about 30° to about 50°, about 35° to about 45°. The frame may be installed in a pipe with a slope angle of about 0°, 5°, 10°, 15°, 20°, 25°, 30°, 35°, 40°, 45°, 50°, 55°, 60°, 65°, 70°, 75°, or about 80°. The frame may be installed in a pipe downstream of a pipe section with a slope angle of between about 0° to about 80° to the vertical.

[0026] The sample device may comprise an optical source for emitting optical radiation through the inspection window. The sample device may further comprise an optical detector adapted to detect optical radiation reflected from the accumulated particulate matter through the inspection window. The sample device may further comprise a processor. The processor may comprise program instructions for irradiating particulate matter accumulated on the sample ledge with optical radiation generated by the optical source. The processor may further comprise program instructions for monitoring reflected optical radiation from accumulated particulate matter on the sample ledge to determine the optical density of the accumulated particulate matter. The processor may further comprise program instructions for determining when the optical density of the accumulated particulate matter is the equivalent of infinite optical density. The processor may further comprise program instructions for measuring one or more attributes of the accumulated particulate matter from the reflected optical radiation received by the optical detector. The processor may further comprise program instructions for activating a jet of gas to be directed from the gas outlet port to the sample ledge to clear the accumulated particulate matter from the sample ledge. In particular arrangements the jet of gas may be directed from the gas outlet port to the ledge from on top of the ledge to clear the accumulated particulate matter from the sample ledge. Alternatively, gas may be directed across the ledge or from the bottom of the ledge to clear the accumulated particulate matter from the sample ledge.

[0027] According to a second aspect of the present invention, there is provided a method for in-line sampling of particulate matter. The method may comprise the step of providing a frame adapted to sealingly engage with a particulate matter transport pipe. The frame may comprise:

a sample ledge adapted to protrude into the pipe to receive and accumulate particulate matter flowing through the pipe;

a housing adapted to receive a sampling device;

an inspection window located within, or adjacent to the sample ledge;

a gas inlet port adapted to receive and transport a jet of gas; and

a gas outlet port adapted to direct the jet of gas to flow across the sample ledge so as to clear accumulated particulate matter from the sample ledge.

[0028] The method may comprise the further step of providing a sampling device comprising an optical source and an optical detector. The method may comprise the further step of irradiating particulate matter accumulated on the sample ledge with optical radiation generated by the optical source. The method may comprise the further step of monitoring reflected optical radiation from accumulated particulate matter on the sample ledge to determine the optical density of the accumulated particulate matter. The method may comprise the further step of determining when the optical density of the accumulated particulate matter is the equivalent of infinite optical density. The method may comprise the further step of measuring one or more attributes of the accumulated particulate matter from the reflected optical radiation received by the optical detector. The method may comprise the further step of activating a jet of gas to be directed from the gas outlet port across the sample ledge to clear the accumulated particulate matter from the sample ledge.

[0029] According to a particular arrangement of the second aspect, there is provided a method for in-line sampling of particulate matter, comprising the steps of:

providing a frame adapted to sealingly engage with a particulate matter transport pipe, the frame comprising:

a sample ledge adapted to protrude into the pipe to receive and accumulate particulate matter flowing through the pipe;

a housing adapted to receive a sampling device;

an inspection window located within, or adjacent to the sample ledge;

a gas inlet port adapted to receive and transport a jet of gas; and

a gas outlet port adapted to direct the jet of gas to flow across the sample ledge so as to clear accumulated particulate matter from the sample ledge;

the method may further comprise the steps of:

providing a sampling device comprising an optical source and an optical detector;

irradiating particulate matter accumulated on the sample ledge with optical radiation generated by the optical source;

monitoring reflected optical radiation from accumulated particulate matter on the sample ledge to determine the optical density of the accumulated particulate matter;

determining when the optical density of the accumulated particulate matter is the equivalent of infinite optical density;

measuring one or more attributes of the accumulated particulate matter from the reflected optical radiation received by the optical detector; and

activating a jet of gas to be directed from the gas outlet port across the sample ledge to clear the accumulated particulate matter from the sample ledge.

[0030] The inspection window may comprise an optically transparent inspection window adapted to permit optical inspection using the sampling device of particulate matter accumulated on the sample ledge.

[0031] The sampling device may further comprise a processor and memory, wherein the processor is configured for: controlling the optical source; receiving and analysing optical signals detected by the detector; and initiating a jet of gas to clear accumulated particulate matter from the sample ledge. The processor may be configured to retrieve program instructions from the memory and execute the program instructions. The program instructions may be configured for:

irradiating particulate matter accumulated on the sample ledge with optical radiation generated by the optical source;

monitoring reflected optical radiation from accumulated particulate matter on the sample ledge to determine the optical density of the accumulated particulate matter;

determining when the optical density of the accumulated particulate matter is the equivalent of infinite optical density;

measuring one or more attributes of the accumulated particulate matter from the reflected optical radiation received by the optical detector; and

activating a jet of gas to be directed from the gas outlet port across the sample ledge to clear the accumulated particulate matter from the sample ledge.

[0032] The gas inlet port may be connected to a compressed gas source.

[0033] The optical density of the accumulated particulate matter on the sample ledge may be measured in real-time or near-real-time. The one or more parameters of the accumulated particulate matter on the sample ledge may be measured in real-time or near-real-time.

[0034] According to a third aspect of the present invention, there is provided a kit for a system for in-line sampling of particulate matter. The kit may comprise an electronic module. The electronic module may comprise a light source. The electronic module may further comprise an optical detector. The electronic module may further comprise a processor. The kit may further comprise a pneumatic module adapted for clearing samples of the particulate off a ledge. The kit may further comprise a curved face plate for in-line attachment of optical, electronic and pneumatic modules to a pipe wherein the curved faceplate is provided in a plurality of options suitable to attach the system to a pipe of a size matching the selected face plate. The kit may further comprise a ledge module configured to connect to the face plate such that, when connected, the ledge is located within the pipe to receive particulate matter flowing through the pipe when in use, wherein the ledge module is provided in a plurality of size and configuration options to suit the slope on the pipe in which the system is to be installed.

[0035] According to a particular aspect of the third aspect of the present invention, there is provided a kit for a system for in-line sampling of particulate matter, the kit comprising:

an optical module comprising:

an optical source; and

a optical detector;

an electronic module comprising:

a processor;

memory; and

a communication module;

a pneumatic module adapted for clearing samples of the particulate off a ledge;

a curved face plate for in-line attachment of the optical, electronic and pneumatic modules to a pipe wherein the curved faceplate is provided in a plurality of options suitable to attach the system to a pipe of a size matching the selected face plate; and

a ledge module configured to connect to the face plate such that, when connected, the ledge is located within the pipe to receive particulate matter flowing through the pipe when in use;

wherein the ledge module is provided in a plurality of size and configuration options to suit the slope on the pipe in which the system is to be installed.

[0036] It will be appreciated that particular features of each of the above aspects may be used with other aspects, embodiments and arrangements of the invention as disclosed herein.

Brief Description of the Drawings

[0037] Notwithstanding any other forms which may fall within the scope of the present invention, a preferred embodiment / preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 shows a cross-section of an in-line particulate sampling device according to the present disclosure;

Figure 2 shows the in-line particulate sampling device of **Figure 1** seen in cross section when engaged with a particulate flow pipe;

Figure 3 shows the process of particulate matter flowing through a pipe and accumulating on a ledge of the in-line particulate sampling device of **Figure 1**;

Figure 4 shows a plot of incident light reflectance from a flour sample showing the wavelength variance of the reflectance amount to define infinite optical density of an accumulated particulate sample of flour;

Figure 5 shows a graph of real-time measurement of moisture content percentage of plurality of particulate matter flows measured using in-line particulate sampling devices of **Figure 1** positioned at various locations and/or in various flow lines in a mill;

Figure 6 shows a graph of real-time measurement of protein content percentage of a plurality of particulate matter flows measured using in-line particulate sampling devices of **Figure 1** positioned at various locations and/or in various flow lines in a mill; and

Figures 7 and **8** show graphs of real-time fault detection using in-line particulate sampling devices of **Figure 1** positioned at various locations and/or in various flow lines in a mill.

Definitions

[0038] The following definitions are provided as general definitions and should in no way limit the scope of the present invention to those terms alone but are put forth for a better understanding of the following description.

[0039] Unless defined otherwise, all technical and scientific terminology used herein have the same meaning as commonly understood by those of ordinary skill in the art to which the invention belongs. It will be further understood that terms used herein should be interpreted as having a meaning that is consistent with their meaning in the context of this specification and the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein. For the purposes of the present invention, additional terms are defined below. Furthermore, all definitions, as defined and used herein, should be understood to control over dictionary definitions, definitions in documents incorporated by reference, and/or ordinary meanings of the defined terms unless there is doubt as to the meaning of a particular term, in which case the common dictionary definition and/or common usage of the term will prevail.

[0040] For the purposes of the present invention, the following terms are defined below:

[0041] The articles *"a"* and *"an"* are used herein to refer to one or to more than one (i.e. to at least one) of the grammatical object of the article. By way of example, *"an element"* refers to one element or more than one element.

[0042] The term *"about"* is used herein to refer to quantities that vary by as much as 30%, preferably by as much as 20%, and more preferably by as much as 10% to a reference quantity. The use of the word *"about"* to qualify a number is merely an express indication that the number is not to be construed as a precise value.

[0043] Throughout this specification, unless the context requires otherwise, the words *"comprise"*, *"comprises"* and *"comprising"* will be understood in an inclusive sense, i.e. to specify or imply the inclusion of a stated feature or step or element or group of steps or elements but not the exclusion or addition of any other feature or step or element or group of steps or elements of further features in various embodiments of the invention.

[0044] Any one of the terms *"including"* or *"which includes"* or *"that includes"* as used herein is also an open term that also means including at least the elements/features that follow the term, but not excluding others. Thus, *"including"* is synonymous with and means *"comprising"*.

[0045] In the claims, as well as in the summary above and the description below, all transitional phrases such as *"comprising"*, *"including"*, *"carrying"*, *"having"*, *"containing"*, *"involving"*, *"holding"*, *"composed of"*, and the like are to be understood to be open-ended, i.e. to mean *"including but not limited to"*. Only the transitional phrases *"consisting of"* and *"consisting essentially of"* alone shall be closed or semi-closed transitional phrases, respectively.

[0046] Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, preferred methods and materials are described. It will be appreciated that the methods, apparatus and systems described herein may be implemented in a variety of ways and for a variety of purposes. The description here is by way of example only.

[0047] The term, *"real-time"*, for example *"displaying real-time data"*, refers to the display of the data without intentional delay, given the processing limitations of the system and the time required to accurately measure the data. Similarly, a process occurring *"in real time"* refers to operation of the process without intentional delay or in which some kind of operation occurs simultaneously (or nearly simultaneously) with when it is happening.

[0048] The term, *"near-real-time"*, for example *"obtaining real-time or near-real-time data"* refers to the obtaining of data either without intentional delay (*"real-time"*) or as close to real-time as practically possible (i.e. with a small, but minimal, amount of delay whether intentional or not within the constraints and processing limitations of the of the system for obtaining and recording or transmitting the data.

[0049] Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, preferred methods and materials are described. It will be appreciated that the methods, apparatus and systems described herein may be implemented in a variety of ways and for a variety of purposes. The description here is by way of example only>

[0050] Also, various inventive concepts may be embodied as one or more methods, of which an example has been provided. The acts performed as part of the method may be ordered in any suitable way. Accordingly, embodiments may be constructed in which acts are performed in an order different than illustrated, which may include performing some acts simultaneously, even though shown as sequential acts in illustrative embodiments.

[0051] The phrase *"and/or"*, as used herein in the specification and in the claims, should be understood to mean *"either or both"* of the elements so conjoined, i.e. elements that are conjunctively present in some cases and disjunctively present in other cases. Multiple elements listed with *"and/or"* should be construed in the same fashion, i.e. *"one or more"* of the elements so conjoined. Other elements may optionally be present other than the elements specifically identified by the *"and/or"* clause, whether related or unrelated to those elements specifically identified. Thus, as a non-limiting example, a reference to *"A and/or B"*, when used in conjunction with open-ended language such as *"comprising"* can refer, in one embodiment, to A only (optionally including elements other than B); in another embodiment, to B only (optionally including elements other than A); in yet another embodiment, to both A and B (optionally including other elements); etc.

[0052] As used herein in the specification and in the claims, *"or"* should be understood to have the same meaning as *"and/or"* as defined above. For example, when separating items in a list, *"or"* or *"and/or"* shall be interpreted as being inclusive, i.e. the inclusion of at least one, but also including more than one, of a number or list of elements, and, optionally, additional unlisted items. Only terms clearly indicated to the contrary, such as *"only one of"* or *"exactly one of"*, or, when used in the claims, *"consisting of"* will refer to the inclusion of exactly one element of a number or list of elements. In general, the term *"or"* as used herein shall only be interpreted as indicating exclusive alternatives (i.e. *"one or the other but not both"*) when preceded by terms of exclusivity, such as *"either"*, *"one of"*, *"only one of"*, or *"exactly one of"*. *"Consisting essentially of"*, when used in the claims, shall have its ordinary meaning as used in the field of patent law>.

[0053] As used herein in the specification and in the claims, the phrase *"at least one"*, in reference to a list of one or more elements, should be understood to mean at least one element selected from any one or more of the elements in the list of elements, but not necessarily including at least one of each and every element specifically listed within the list of elements and not excluding any combinations of elements in the list of elements. This definition also allows that elements may optionally be present other than the elements specifically identified within the list of elements to which the phrase *"at least one"* refers, whether related or unrelated to those elements specifically identified. Thus, as a non-limiting example, *"at least one of A and B"* (or, equivalently, *"at least one of A or B"*, or, equivalently *"at least one of A and/or B"*) can refer, in one embodiment, to at least one, optionally including more than one, A, with no B present (and optionally including elements other than B); in another embodiment, to at least one, optionally including more than one, B, with no A present (and optionally including elements other than A); in yet another embodiment, to at least one, optionally including more than one, A, and at least one, optionally including more than one, B (and optionally including other elements); etc.

[0054] For the purpose of this specification, where method steps are described in sequence, the sequence does not necessarily mean that the steps are to be carried out in chronological order in that sequence, unless there is no other logical manner of interpreting the sequence.

[0055] In addition, where features or aspects of the invention are described in terms of Markush groups, those skilled in the art will recognise that the invention is also thereby described in terms of any individual member or subgroup of members of the Markush group.

Detailed Description

[0056] It should be noted in the following description that like or the same reference numerals in different embodiments denote the same or similar features.

[0057] Referring to the figures, **Figure 1** shows a perspective view of a cross section of an in-line particulate sampling system **100** comprising a sampling system device frame **101** adapted to engage with a particulate matter flow pipe **50** as used in, for example, a flour or grain mill, to transport particulate matter **200**. The system **100** described below may also be used for sampling and analysis of a variety of particulate flow within a pipe including, for example, a range of grains including soy, oats, chickpeas feed grains etc.; powdered foods such as powdered milk; or powdered pharmaceutical products, either as a precursor to formation of tablet form of pharmaceutical or for processing of powdered products.

[0058] **Figure 2** shows a cross section of sampling system **100** adapted to be installed in-line with a pipe for particulate flow. Sampling device frame **101** is placed in the pipe and comprises a sample ledge **103** which protrudes into pipe **50** such that ledge **103** is located in the particle flow **200** of the pipe **50** without interfering with overall flow **200**. Frame **101** comprises a curved face plate **104** and pipe engagement notches **102a** and **102b** adapted to engage with a pipe of similar diameter as curved face plate **104**. In particular embodiments, frame **101** is provided in various sizes having a curved face plate **104** having a curvature of a particular diameter such that system **100** may be installed in pipes **50** of various diameters by selection of the appropriate frame **101**. The sampling system **100** does not require moving parts within the pipe **50**. It is also designed to minimise disruption to the flow **200** and to avoid potential damage to the sampling system **100** itself which may be caused by the particles **200** flowing through the pipe **50**. This significantly reduces the risk of operational problems with the device **100**. It is also designed to avoid potential damage caused by the particles **200** (hard fine particles moving at a high velocity can cause significant abrasion), therefore probes or other devices that protrude into the particulate flow, as observed in prior sampling and/or measurement solutions, can experience problems. The system **100** is also designed to be food safe and so there is no risk of contamination of the flow with physical objects of system **100** which come into contact with the particles **200** during use.

[0059] Sampling device frame **101** is configured to engage with a flow pipe **50** of a particular diameter, by first removing a section of the pipe wall and inserting sampling device frame **101** into the hole. Sampling device frame **101** comprises upper lip **101a** and lower lip **101b** which engage with the edges of the hole cut into the pipe to seal the pipe with sampling device **100** installed therein.

[0060] The modular embodiment of particulate sampling system 100 enables the system 100 to be installed in pipes of varied sizes and configurations in accordance with requirements.

[0061] Sampling device frame **101** further comprises a ledge **103** which protrudes into the interior of the pipe when frame **101** is installed therein. Ledge **103** is configured to be inserted into the flow of particulate matter such that a sample of particles in the particulate flow accumulates on the ledge **103**. Ledge **103** comprises a sealed, optically transparent inspection window **105**. Window **105** may be located either within or adjacent to the ledge **103** such that that accumulated particulate matter **201** on ledge **103** covers the inspection window **105** thereby to permit illumination of the accumulated particulate matter **201** by light **113** emitted from an optical source **111** of the system **100**.

[0062] The sampling device frame **101** comprises a compartment **107** external to the pipe which is adapted to receive an optical sampling device **109** (in **Figure 2**) that measures when there is adequate optical density to take a measurement of reflected light that maximises the signal to noise ratio. Optical sampling device **109** further comprises an optical module **130** comprising an optical light source **111** such as a laser source or lamp source. The optical source **111** may comprise a laser source which may, for example, be an infrared laser source. The optical source **111** may be a lamp, for example a halogen lamp source, which emits light aver a broad wavelength range. An optical grating (not shown) may be located in the optical module **130** to permit tuning or scanning of the wavelength of light **113** emitted by broadband optical source **111** which is directed through window **105** onto the accumulated particulate matter **201** on sample ledge **103**.

Scanning or tuning the wavelength of the emitted light **113** enables measurement of spectral reflectance / absorption data of the accumulated particulate matter **201**. In particular arrangements the light source may be adapted to emit light with a fixed wavelength, or equivalently, the combination of a broadband light source and a grating may be operated in a static or non-scanning mode where the light permitted to exit window **105** and illuminate the accumulated particulate matter **201** on ledge **103** is fixed at a desired wavelength and the attributes of the particulate matter **200** can be measured over time at the chosen wavelength.

[0063] The light source may be adapted to emit light at a desired wavelength or wavelength range, for example, the emitted light may be ultraviolet (with wavelengths of about 100 – 400 nm), -visible (with wavelengths of about 400-750 nm), near-infrared (with wavelengths of about 750-2500 nm), short-wavelength infrared (e.g. about 1300-1600 nm), mid-infrared light (with wavelengths of about 2,500-15,000 nm), or far-infrared light (with wavelengths of about 15,000 nm - 1 mm) to obtain spectral information of the particulate matter in the pipe.

[0064] Compartment **107** is configured to receive the sampling device such that the optical source **111** is aligned with ledge window **105** so that light **113** emitted from the optical source **111** passes through window **105** to irradiate particulate matter **200** which has accumulated over time onto ledge **103**. Reflected light from accumulated sample **201** on ledge **103** is transmitted back through window **105** for detection by an optical detector **115** housed in optical module **130** within compartment **107** of the sampling system **100** to obtain absorption and/or spectral information with respect of the accumulated particulate matter **201**. In particular arrangements, optical source **111** may comprise a narrow linewidth optical source **111** for measurement of absorption and/or spectral information at a selected frequency (wavelength) corresponding to the frequency (wavelength) of light emitted by optical source **111**. In alternate arrangements, optical source **111** comprises either a broadband optical source, multi-frequency source (capable of emitting light at a plurality of frequencies, which may be distinct from each other) or frequency-scanning (tunable) optical source for measurement of absorption and/or spectral information of accumulated particulate matter **201** at one or more optical frequencies of light able to be emitted by source **111**.

[0065] The sampling device housed in compartment **107** also comprises an optical detector **115** which continuously measures the reflected light from the particles accumulated on ledge **103**. The sampling device is initially placed in a "*wait*" mode which is designed to determine when there is sufficient accumulated particulate matter **201** on ledge **103** to be able to take as accurate and representative measurement of the properties of the accumulated particulate matter **201**. In the *wait* mode, the sampling device **109** is continuously measuring the reflected light from the accumulated particulate matter **201** on ledge **103** with detector **115** to determine either:

- when the accumulated sample **201** provides the equivalent of infinite optical density (i.e. the accumulated sample **201** is dense enough that light **113** from the optical source **111** is not lost by transmission through the accumulated sample **201** or, alternatively,

- when there is adequate optical density in the particles **201** accumulated on ledge **103** to allow accurate and reproducible optical measurements to be made.

[0066] Compartment **107** is advantageously adapted for housing one or more sampling devices **109** or optical modules **130** interchangeably such that sampling devices may be swapped in or out of sampling system **100** e.g. for specific measurement and analysis of the accumulated particulate matter **201**. For instance, a particular sampling device **109** comprising, for example, a near-infrared optical source **111** adapted for emitting light **113** having a wavelength between about 800 nm to about 2,500 nm may be housed in compartment **107** for measurement of particular parameters of the particles in particle flow **200** at a predetermine location in the particulate process whereas a different sampling device **109** or optical module **130** may be housed in a second sampling position (not shown) and having an optical source adapted for emitting light at a different wavelength (e.g. a visible wavelength between about 400 nm to about 750 nm; an ultraviolet wavelength between about 100 nm to about 400 nm; a mid-infrared wavelength between about 2,500 nm to about 15,000 nm; or a far infrared wavelength between about 15,000 nm to about 1 mm).

[0067] Sampling device **109** further includes an electronic module **110** housed within device **109** for controlling the components of system **100**. Electronic module **110** comprises a processor **112** and memory **114** comprising volatile and non-volatile memory portions. Processor **112** is adapted to retrieve and execute program instructions stored in memory **114**. Program instructions in a particular arrangement include instructions for:

irradiating particulate matter **200** accumulated **201** on the sample ledge **103** with optical radiation **113** generated by optical source **111**; monitoring reflected optical radiation **116** detected by detector **115** from accumulated particulate matter **201** on the sample ledge **103** to determine the optical density of the accumulated particulate matter **201**; determining when the optical density of the accumulated particulate matter **201** is the equivalent of infinite optical density; measuring one or more attributes of the accumulated particulate matter **201** from the reflected optical radiation **116** received by the optical detector **115**; and activating a jet of gas to be directed from the gas outlet port **119** across the sample ledge **130** to clear the accumulated particulate matter **201** from the sample ledge **103**. The one or more attributes of the particulate matter **200** may include one or more of, for example: moisture, ash; protein, colour, ash, starch, damage and/or oil content. Other characteristics of particulate matter **200** may also be measured as would be appreciated by the skilled addressee dependent on the nature of the particulate matter **200**. Measurement of the characteristics of particulate matter **200** may comprise analysis of the light **113** absorbed by particulate matter **200** and/or reflected light from particulate matter **200**. The analysis may comprise one or more of spectroscopic analysis, absorption analysis, or transmission analysis.

[0068] Electronic module **110** further includes a communication module **118** for wired and/or wireless communication with system **100**. Communication module may be a wired network, such as a wired Ethernet™ network, or a wireless network, such as a Bluetooth™ network, IEEE 802.11 network, or cellular network (e.g. a 3G or 4G telecommunications network). The communication module **118** may be adapted to connect to a local area network (LAN), such as a home or office computer network, or a wide area network (WAN), such as the Internet, or a private WAN.

[0069] The processor **112** may be a reduced instruction set computer (RISC) or complex instruction set computer (CISC) processor or the like. Memory **114** may be a magnetic disk hard drive or a solid-state disk drive. Computer program code instructions may be loaded into memory **114** or from a connected network using communication module **118**. An operating system and one or more software applications are loaded from memory **210** into processor **112**. The processor **114** decodes the instructions into machine code, executes the instructions and stores one or more intermediate results in memory **114**.

[0070] In this manner, the instructions stored in the memory **114**, when retrieved and executed by the processor **112**, may configure system **100** as a special-purpose machine that may perform the functions described herein.

[0071] Once the sampling device **109** makes the determination (from the optical density measurement) that an accurate measurement can be made, it switches into a "*measure*" mode to measure and analyse the reflected optical signals from the accumulated particulate matter **201** on ledge **103** to record spectral information of the particulate matter **201** including reflected spectra from the particulate matter **201**.

[0072] In alternate arrangements, system **100** may include a second detector (not shown) positioned above sample ledge **103** and adapted to receive and detect light from the optical source **111** which has passed through window **105** and/or through any accumulated particulate matter **201** on sample ledge **103**. The second detector may be adapted to measure optical transmission of light emitted by source **111** through accumulated particular matter **201** on ledge **103** to determine the optical density of the accumulated particles **201** or, in other arrangements, the second detector may be adapted to also measure spectral attributes of particulate matter **200** by detecting the wavelength dependence characteristics of light transmitted through the particles **201**.

[0073] The system **100** is advantageously connected to a compressed gas source for supply of gas flow to clear the accumulated particulate matter **201** from ledge **103** after each measurement. Once the measurement is completed a jet of compressed gas, (for example, air, ambient air or an inert gas such as, for example nitrogen) is used to clear particulate matter **201** from ledge **103**. In particular embodiments, the system **100** includes a pneumatic module configured to utilise compressed air from a pneumatic system **203** associated with the mill in which the system **100** is installed, since this is readily available in all mills and is cheap. However, any compressed gas can be used, including inert gases or air, the key criteria being that the gas is at sufficient pressure to clear the particulate matter **201** from ledge **103** in preparation to receive further particulate matter flowing through pipe **50** for a subsequent measurement. An example embodiment uses compressed air from pneumatic system **203** having a pressure of about 600kPa, because this is what is readily available in a typical flour mill, and this has been found to work well with prototypes of the in-line particulate sampling system **100** disclosed herein. However, typical pressures in the range of about 100 kPa to about 1000kPa, preferably about 200kPa to about 800kPa, may be used.

[0074] In other embodiments, the pressurised gas used to clear the particulate matter **201** from the ledge **103** has a pressure of about or greater than 200kPa and preferably greater than about 300kPa. Referring to **Figure 1**, in use, the pneumatic module receives the pressurised gas into inlet port **117** and directs it to one or more outlet ports or nozzles **119** (or an array of such outlet ports) directed at ledge **103** to blow the accumulated particulate matter **201** from ledge **103** thereby enabling system **100** to self-clean the ledge **103** on demand (initiated by a control signal from processor **112** of device **109**) and make it ready to receive further particulate matter **200** from the particulate flow in the pipe **50** to conduct a further measurement. In a particular arrangement, for example, as depicted in **Figure 1**, nozzle **119** is an elongate aperture extending the length of sample ledge **103** and in fluid communication with inlet port **117** to receive air flow from a connected pneumatic system **203**. Once the ledge **103** is cleared with the compressed gas, the sampling device **109** switches back to the *wait* mode to monitor further particles **201** accumulating on ledge **103** as before until a sufficient optical density of the particles is achieved for a further measurement to occur.

[0075] The sampling rate (i.e. the time between measurements recorded by the sampling device **109**) will depend on the rate of flow of particulate matter **200** within the pipe. Pipes with high particulate flow rate will accumulate particulate matter **201** on ledge **103** quickly such that the required optical density of accumulated particulate matter **201** will be achieved quickly. Thus, the sampling rate will be higher than for a system **100** installed in a pipe which has a low particulate flow rate through the pipe.

[0076] The accumulation rate of particulate matter **201** on sample ledge **103** can also be utilised to identify potential faults on the mill process. For example, a typical fault in the mill process will result in a change in the flow rate of particulate matter **201** through the pipes **50**. A fault in the mill process will usually result in a reduction or complete stoppage of particulate matter flow through the pipes. This reduction in flow rate is readily recognised by system **100** as either a reduced rate of particulate matter **201** accumulation on sample ledge **103** (in event of a reduction in flow) or no particulate matter sample accumulation on sample ledge **103** as expected from past or historical sample rates. Conversely, in certain circumstances a fault in the mill process may result in an increase in the flow rate or quantity of particulate matter **201** flowing through pipes **50**. In this case, an increase in the accumulation rate of particulate matter **201** on sample ledge **301** may also be identified as a fault in the mill process and appropriate alerting of mill staff or commencement of remedial actions may be undertaken by system **100**.

[0077] A further example of fault detection in a working mill may include monitoring the levels of particular mill products and/or by-products, such as, for example, ash content in the particulate flow. A tear in the plansifter screen will result in contamination of bran and germ in the flour stream resulting in an increase in the ash content. When a sudden or gradual increase in ash occurs over a relatively short period of time, this is a sign that there is a tear in the screen or leakage of undesirable by-products into the flour stream. This will contaminate the end product. The system **100** can be used to not only identify that this has occurred, for example by a sudden increase in the ash level resulting from a burst screen, but also identify the zone of the mill where the fault has occurred enabling the miller to take quick corrective action.

[0078] **Figure 3** shows a particular arrangement of a pipe **50** and a ledge **103** protruding into the interior of pipe **50** into the particulate flow **200** flowing through the pipe. Pipe section **51** upstream of ledge **103** is connected to a vertical section **53** of pipe **50** in which sampling system **100** comprising ledge **103** is installed. Particles **200** flowing through pipe section **51** flow onto the wall of the vertical pipe section **53** wherein the sampling system **100** is installed such that ledge **103** is located on the wall impacted by the particles **200** such that particles begin to accumulate on ledge **103** for optical measurement as described above when the optical density of the accumulated particles **201** is sufficient. System **100** may be installed in a flow pipe **50** of the mill with a slope angle **55** between 0° to about 80° to the vertical. In alternate arrangements, for example in a mill line configured for relatively low flow levels compared to flows in a typical commercial mill arrangement, the sampling system **100** may in installed in a pipe with a slope angle **55** between about 0° to about 45°, preferably between about 10° to about 20° to the vertical to ensure sufficient engagement of the particulate flow **200** through pipe **50** with the ledge **103** of the sampling system **100**. In particular arrangements, the sampling system **100** is installed in a vertical section **53** in pipe **50** which is downstream of a sloping section **51** of pipe **50** wherein the sampling system **100** is advantageously installed at a distal wall **54** of pipe section **53** (as depicted in **Figure 3**) thereby to receive the particulate matter **200** as it falls through pipe **50** onto sample ledge **103** adjacent or protruding into pipe **50** from distal wall **54**. The sloping section **51** of pipe **50** may have an angle to the vertical of between about 0° to about 80° to the vertical.

[0079] The particular advantages of particulate flow system **100** described above include:

- It works in both high and low flow rate situations – only the sampling rate will be affected for pipes of different flow rates>
- It continually measures in real-time, or near-real-time, the optical density of the accumulated particles **201** on ledge **103** to automatically determine when there is enough accumulated particulate matter **201** to perform an accurate and reproducible optical measurement of the properties of the particles flowing in the pipe.
- It is self-cleaning through the use of a directed jet of air or inert gas flow over the ledge **103** to clear the accumulated particles **201** and ready the system **100** for accumulation of further particles in the flow for subsequent measurements.

[0080] In particular embodiments, the particulate sampling system **100** may be manufactured and provided in a kit form comprising:

- a module or modules including the electronic and optical systems (i.e. optical source **111**, optical detector **115**, and processing (**112**) / memory (**114**) capability) and pneumatic systems for clearing the samples off the ledge – in particular embodiments, the optical, electronic systems and/or the pneumatic systems may be included with a frame **101** provided in the kit;
- a curved face plate **104** for attaching the optical, electronic and pneumatic systems to the pipe **50** in which the system **100** is to be installed wherein the curved face plate **104** is provided in a plurality of options suitable to attach the system **100** to a pipe **50** of a size matching the selected face plate **104**;
- a ledge module comprising ledge **103** that is provided in a plurality of ledge options and a range of sizes to suit the slope **55** on the pipe **50** at the location in which the system **100** is to be installed.

[0081] Sample system 100 may, in some arrangements comprise a plurality of optical sources. For example, a first optical source may be adapted to monitor the optical density of the accumulated particulate matter 201 on the sample ledge 103. When the particulate matter reaches a desired optical density, a second optical source may be activated to irradiate the accumulated particulate matter 201 such that the radiation from the second optical source which is reflected from accumulated particulate matter 201 is detected by optical detector 115 for analysis of one or more properties of the accumulated particulate matter 201.

[0082] In particular arrangements, the same detector device **115** is used to make both the optical density measurement and the final measurement as described above. During the *"wait"* mode of the system **100**, the detector **115** is advantageously used in a fast "*measure*" mode as would be appreciated by the skilled addressee (for example, with low (short) integration time or scan time e.g. of less than 10 seconds) to make a rapid determination of optical density of the particulate matter **201** as it accumulates on ledge **103**. Once a desired optical density is reached, the system **100** switches to the *measure* mode (via the processor of sample device **109**) wherein the integration time or scan time of detector **115** is increased to measure spectral information of the particulate matter **200** accumulated on ledge **103**. In particular arrangements of system **100**, it is configured to monitor the accumulated particulate matter **201** in the *wait* mode until infinite optical density at the measurement wavelength is achieved. In these arrangements, infinite optical density is a function of the measurement wavelength for a particular substance to be tested (e.g. flour particulate matter flowing in pipes in a flour mill as discussed above). At a selected measurement wavelength (i.e. the wavelength of light emitted by optical source **109**), infinite optical density is defined in accordance with two criteria:

1. Zero, or near-zero transmission

[0083] Zero, or near-zero transmission (e.g. less than 3%, preferably less than 1% transmission) of the measurement wavelength through the accumulated particulate matter **201** i.e. the sample is considered to have achieved infinite optical density (the accumulated sample **201** is dense enough that light from the optical source **109** is not lost by transmission through the accumulated sample **201**) when the reflectance at the measurement wavelength is greater than a defined limit for the selected wavelength.

[0084] Specifically, infinite optical density is considered to be achieved when no light from optical source **109** is transmitted through the accumulated particulate sample **201** on the ledge **103**. This means that the light from source **103** is either: absorbed by the constituents comprising particulate sample **201** (e.g. moisture, starch, protein, fibre, etc); scattered by the accumulated particulate matter **201** (dependent upon the size and shape of the particles on ledge **103**; or is reflected back to detector **115** housed in system **100**. For example, referring to **Figure 4**, at a wavelength of 1350nm, the signal reflected from the accumulated sample **201** to achieve infinite optical density must be greater than 75% of the incident light. The required level of reflectance can be set for different wavelengths. At each specific wavelength, the required reflectance will be different depending upon the sample absorption at the chosen wavelength and the wavelength and particle dimension dependence on scattering of the specific chosen wavelength.

[0085] For example, at a chosen source wavelength of 1350nm from source **109**, infinite optical density is achieved with a reflectance of about 75% of the source light: at 1800nm, infinite optical density occurs at a reflectance of about 50%; and at 2200nm, infinite optical density occurs at a reflectance of about 30% reflectance from the accumulated sample **201**. To determine infinite optical density, reflectance at a single or at multiple wavelengths can be used.

[0086] In particular alternate arrangements, a secondary detector (not shown) may be provided above ledge **103** to measure the transmission of light from optical source **109** through the particulate matter as it accumulates **201** on ledge **103**. In this arrangement for measuring the optical density, the secondary detector would only be active during the *wait* mode of sampling system **100** and would monitor the transmitted light from source **109** until approximately no light (for example the transmitted light detected falls to below about 1% of the peak transmitted light when no sample is present on ledge **103**) is transmitted indicating that infinite optical density had been achieved, at which time system **100** switches to the *measure* mode to record spectral information of accumulated particulate matter **201** from reflected light from source **109** detected by detector **115** housed within system **100**.

2. Zero- or near-zero change

[0087] Zero- or near-zero change (e.g. less than 3%, preferably less than 1% change) in reflected (or transmitted) light measurements, i.e. the sample is considered to have achieved infinite optical density when consecutive scans over a predetermined time (for example, between about 5s to 30s, and preferably about 10 seconds or less) result in a percentage change in the reflectance of less than about 3%, and preferably less than about 1%.

[0088] In this method, infinite optical density is considered to have been achieved when measurement of the light reflected from accumulated sample **201** no longer changes between successive measurements by detector **115**.

[0089] As noted above, infinite optical density of the accumulated particulate matter **201** is not a strict requirement for obtaining sample measurements as the optical density only needs to be sufficiently high to achieve meaningful and repeatable results, which would depend on the specific requirements of the measurement goals. However, where the application permits the additional time necessary to allow the accumulated particulate matter **201** to build up to a quantity sufficient to achieve infinite optical density, this would likely be preferred for measurement consistency.

[0090] In particular arrangements of system **100**, a measurement wavelength of 1350nm is selected, however, wavelengths other than 1350nm could be used and for each wavelength the percentage of sample reflectance corresponding to infinite optical density would be different. **Figure 4** shows a graph of the % reflectance (plot **41**) of a sample of flour corresponding to infinite optical density of flour particulate matter as a function of wavelength. **Figure 4** indicates that at longer measurement wavelengths, the sample reflectance necessary to meet the criteria of infinite optical density for flour is less than 40% or even as low as about 30% for a measurement wavelength of about 2500nm.

[0091] In further arrangements, it is possible that sample device comprises an optical source and optical detector located above ledge **103** and the monitoring of accumulating particulate matter and sample spectral measurements may be obtained in a reflectance mode from above ledge **103** (and thus potentially negating the need for window **105** on ledge **103**), however, this configuration is considered to be a more difficult configuration and would provide no significant, if any, advantage over housing the optical source **109** and detector **115** below ledge **103** within sampling system **100**.

[0092] Sample system **100** further comprises a processor and memory connected, at least, to the optical source(s), the optical detector and the compressed gas source. The memory comprises program instructions which are executed by the processor to autonomously perform real-time or near-real-time sample analysis of the particulate matter flowing through the pipe **50**. In a particular arrangement, the program instructions are executed to perform a method comprising the steps of: irradiating particulate matter **200** accumulated **201** on the sample ledge **103** with optical radiation generated by optical source **111**; monitoring reflected optical radiation from accumulated particulate matter **201** on the sample ledge **103** to determine the optical density of the accumulated particulate matter **201**; determining when the optical density of the accumulated particulate matter **201** is the equivalent of infinite optical density; measuring one or more attributes of the accumulated particulate matter **201** from the reflected optical radiation received by the optical detector **115**; and activating a jet of gas to be directed from the gas outlet port across the sample ledge to clear the accumulated particulate matter **201** from the sample ledge **103**.

Example Operation

[0093] Sensor system **100** has been extensively tested in an experimental flour mill having a capacity of 650 kg per hour which, whilst a reduced rate from commercial mill operations, is sufficient for comparative results to commercial mills, whilst being small enough to suit training and research activities. The test mill includes 4 break passages, 7 reduction passages, pin mills and detachers, 2 purifiers and a plansifter. Thus, the test mill is able to conduct meaningful and scalable test situations for a full milling evaluation, including cumulative ash and protein curves on batch sizes as small as only 1000kg of wheat. In the operational examples described herein, system **100** was fitted with an optical source comprising a halogen lamp adapted for emitting light in the 1200 nm to 2600 nm range, in conjunction with an optical grating (not shown) to tune the wavelength range and scan the accumulated particulate matter **201** across the effective output range of the halogen lamp source **111**. The optical power of light **113** permitted to illuminate the accumulated particulate matter **201** must be low enough so as to not result in heating of the accumulated particles **201** as this will change the measured properties. In the present examples, the total light output of the halogen lamp source **111** was limited to a maximum of 3 watts. As would be readily appreciated by the skilled addressee, the spot size of light **113** on sample **201** may be varied as a function of optical power to maintain an illumination fluence below the threshold of discernible heating of sample **201**.

[0094] **Figure 5** shows a graph of the results from the sample system **100** in operation for real-time monitoring of the %Moisture content of milled wheat initially prepared in the test mill with two conditioning levels of 15% and 18%. The data is accumulated over a time period of about 1 hour and 15 minutes.

[0095] Plotline **51** is a measure of milled wheat particles flowing in the head break stream of a mill which was originally conditioned at 18% moisture content. As can be seen in **Figure 5**, at the point of measurement by system **100**, the moisture content has already dropped to less than 15.5%. This is attributed to loss of moisture in the pneumatics of the mill where the humidity was 65% during milling. Plotline **53** is a measure of milled wheat particles flowing in the head break stream of a mill which was originally conditioned at 15% moisture content which, at the point of sampling, has dropped by less than 1% which indicates that it is closer to the equilibrium moisture point on the mill process. Plotline **55** is the straight-run flour from the 18% conditioned wheat and, finally, plotline **57** is the straight-run flour milled from the wheat conditioned to 15%. In the present example, the multiple inline sensor system devices **100** are showing how quickly the moisture of the flour can change from the original conditioning level and just how significant the milling process is on final moisture content compared to the conditioning level. Real-time data as made possible with sensor system devices **100** enables real-time or near-real-time adjustments within the mill process to maintain the milled flour with desired characteristics. With this information gathered in-line, and in in real time, it is now possible to better control the moisture content of the final processed flour to customer specifications.

[0096] **Figure 6** shows a plot of the protein content of milled flour, produced from wheat with a protein content of 12.8%, over a time period of nearly 5 hours. For simplicity, only four mill streams are shown of a total of 11 streams sampled using a plurality of sensor system devices **100**. Plotline **61** is the tail break flour which has a protein content of 16%. This high protein content is associated with the endosperm material scraped from the bran. Plotline **63** is the head break mill line with a protein content of 14%. Plotline **65** is the straight-run flour (all streams combined) at 12% protein content. Finally, plotline **67** is the head-reduction flour (flour from the heart of the wheat grain endosperm) with protein content of less than 10%.

[0097] As can be seen from **Figure 6**, the streams of particulate matter **200** in the mill have a range of 6% protein content and it can be seen that the mill is operating in a steady state. The protein values measured by sensor system devices **100** are typical of each stream operation over time. It is clear that use of a plurality of sensor system devices

100 in the present example of a flour processing mill (i.e., at least one on each mill stream of particulate matter **200** – and possibly multiple sensor devices on each stream at different locations in the milling process) to provide real-time data on the particulate matter characteristics is invaluable and can readily permit rapid detection of undesirable particulate characteristics in each stream. This has clear advantages of, for example, being able to remove a particular stream that was not performing to specification, or indeed providing the real-time ability to remove or blend streams of different characteristics to meet a desired specification such as, for example, a specific moisture or protein content percentage in the final product, which has great potential when manufacturing multiple flour products from a single wheat grist.

[0098] **Figure 7** shows an example of a fault detection using a sensor system device **100**. In particular, **Figure 7** shows a real-time measurement of ash percentage **71** on the head break stream in the test mill.

[0099] In the test milling run depicted in **Figure 7**, the raw input material was being pre-dampened prior to milling. Pre-dampening or conditioning is used to plasticize the bran to reduce shattering which creates fine particles of bran which are difficult to separate from endosperm. The addition of moisture prior to milling also softens the endosperm to reduce the energy required for grinding. However, a choke in the mill line developed at time **73**. In response to the choke, the ash content percentage in the particulate matter **200** at the location of the sensor system device **100** experienced wild fluctuations which are shown detected in real-time in **Figure 7** between times **73** and **75**. Once the choke was cleared from the mill lines at time **75**, the ash content percentage returned to normal levels.

[0100] A further example of fault detection and rectification is shown in **Figure 8** which shows a real-time graph of the protein percentage of particulate matter in a flour milling trial for the first/second break stream (plotline **81**) and A-stream (A-STR, plotline **83**). Normal protein results are seen in the head break stream **81** however abnormal data was immediately noticed on the head reduction A-STR **83**. The miller was able to use the lack of infinite optical density on A-STR **83** to identify that the rolls had not engaged correctly meaning that the flour flowed through the rolls without any grinding, which resulted in insufficient flour production to achieve infinite optical density at the sensor system device **100**. On inspection, it was identified by the miller that the first reduction roller had not been properly engaged. As soon as the roller was engaged and the flour was ground, at time **85**, the flour started to flow through to the A stream flour and infinite optical density was achieved and the protein levels immediately returned to normal levels at around 10%. In the absence of real-time sensor system devices **100**, this type of fault would likely go unnoticed for an entire shift in a commercial milling operation, however, with real-time monitoring provided by sensor system devices **100** the fault was identified and rectified less than 45 minutes into the trial.

[0101] As can be seen in **Figures 5** to **8**, real-time monitoring of the characteristics of the particulate matter in the milling process is extremely useful in evaluating the characteristics of the particulate matter **200** for the mill process, and also for rapidly detecting and rectifying faults in the mill lines to preserve integrity of the milling process and reducing product wastage and mill downtime. It will be readily appreciated by the skilled addressee that monitoring of one or more characteristics of the particulate matter for sudden, rapid and/or unusual changes may be linked with an alarm system to the mill control center so that the mill process can be halted if necessary whilst the fault is rectified. Also, deployment of a plurality of sensor system devices **100** throughout the mill, in conjunction with alert monitoring, will aid in rapidly isolating any detected faults which, in a large mill operation may enable only an affected section to be taken off-line while the fault is rectified rather than taking the whole mill offline while a fault is located, and which likely has only been detected in a final product with potential for significant wastages. It will be readily appreciated that such a deployment of a plurality of sensor system devices **100** throughout a large commercial mill operation will provide significant benefits and maximization of process throughputs, for example in increased quality of the mill output products) and commercial profits. Real-time automatic monitoring of the mill process using a plurality of sensor system devices **100** also has the advantage of providing real-time inputs to computer control systems for mill automation and also online monitoring whereby the mill process may be monitored and controlled in real-time from a remote location.

[0102] Furthermore, real-time monitoring of the characteristics of the particulate matter **200** in the milling process as measured in real-time by one or more systems **100** can readily be integrated with artificial intelligence and/or machine learning systems to optimize the milling process. Real-time data can be used to increase milling yields which is the amount of flour produced from the incoming wheat. Modern flour mills are fitted with Supervisory Control And Data Acquisition (SCADA) systems that monitor and record mill settings. Processor **112** may be interfaced with real-time flour stream quality data with the SCADA system to facilitate machine learning as would be readily appreciated by the skilled addressee. Recording and storing historical process data information on mill and feed stock changes and how that impacts in the flour stream quality will readily facilitate the development of computational or machine learning models that will enable the mill to "learn" and adjust the mill process variables to account for variations in input feedstock characteristics and/or adjust the milling process in real-time to meet quality requirements of the output product. For example, the recorded data may be used to optimise the extraction rate, regulate production and optimise profitability of the mill process. The data will support linear programming models and machine learning to improve mill performance and automation.

[0103] Data from the sensor system devices **100** can be used for linear programming to optimise flour blending. For example, commercial flour mills may produce a range of flour products that are required to meet specific customer quality targets, with each flour product having different quality requirements and values. Examples of different flour qualities may be a white premium noodle flour with a target ash of 0.4%, instant noodle flour with a target ash of 0.55% and general-purpose flour with a target ash content of 0.65%. These different products can be produced simultaneously from a single grist by blending multiple flour streams to produce target flour quality. The use of real time flour stream quality measurements enables the mill to use linear programming, or similar techniques, to optimise the flour stream blending to ensure that target product qualities are achieved while maximising yield and reducing the production of low value by-products.

[0104] Another example on how the use of the inline sensors can be used to optimise the flour milling process is through machine learning. In milling wheat into flour, the wheat is normally conditioned, which is a process of adding water to the wheat and tempering for up to 24 hours. The conditioning of wheat amplifies the structural difference in properties between the endosperm with the bran and germ, therefore improving the ability to detach the endosperm from the bran and germ in the grinding stage and separate in the separation stages of the flour mill. Normally, the miller targets a wheat moisture content between 15-18%. Carrying out milling at differing levels of conditioning in experimental trials, the inline sensor system devices **100** were able to measure the effect of conditioning level on the individual flour streams and models could therefore be developed that were able to predict flour quality, at each stream, as a result of the impact of conditioning on flour quality. The models can then be used to optimise the required conditioning level to achieve the final target flour quality.

Interpretation

In Accordance With

[0105] As described herein, ‘in accordance with’ may also mean ‘as a function of’ and is not necessarily limited to the integers specified in relation thereto.

Processes:

[0106] Unless specifically stated otherwise, as apparent from the following discussions, it is appreciated that throughout the specification discussions utilizing terms such as “processing”, “computing”, “calculating”, “determining”, “analysing” or the like, refer to the action and/or processes of a computer or computing system, or similar electronic computing device, that manipulate and/or transform data represented as physical, such as electronic, quantities into other data similarly represented as physical quantities.

Processor:

[0107] In a similar manner, the term “processor” may refer to any device or portion of a device that processes electronic data, e.g., from registers and/or memory to transform that electronic data into other electronic data that, e.g., may be stored in registers and/or memory. A “computer” or a “computing device” or a “computing machine” or a “computing platform” may include one or more processors.

[0108] The methodologies described herein are, in one embodiment, performable by one or more processors that accept computer-readable (also called machine-readable) code containing a set of instructions that when executed by one or more of the processors carry out at least one of the methods described herein. Any processor capable of executing a set of instructions (sequential or otherwise) that specify actions to be taken are included. Thus, one example is a typical processing system that includes one or more processors. The processing system further may include a memory subsystem including main RAM and/or a static RAM, and/or ROM.

Wireless:

[0109] The invention may be embodied using devices conforming to other network standards and for other applications, including, for example other WLAN standards and other wireless standards. Applications that can be accommodated include IEEE 802.11 wireless LANs and links, and wireless Ethernet.

[0110] In the context of this document, the term “wireless” and its derivatives may be used to describe circuits, devices, systems, methods, techniques, communications channels, etc., that may communicate data through the use of modulated electromagnetic radiation through a non-solid medium. The term does not imply that the associated devices do not contain any wires, although in some embodiments they might not. In the context of this document, the term “wired” and its derivatives may be used to describe circuits, devices, systems, methods, techniques, communications channels, etc., that may communicate data through the use of modulated electromagnetic radiation through a solid medium. The term does not imply that the associated devices are coupled by electrically conductive wires.

Means For Carrying out a Method or Function:

[0111] Furthermore, some of the embodiments are described herein as a method or combination of elements of a method that can be implemented by a processor or a processor device, computer system, or by other means of carrying out the function. Thus, a processor with the necessary instructions for carrying out such a method or element of a method forms a means for carrying out the method or element of a method. Furthermore, an element described herein of an apparatus embodiment is an example of a means for carrying out the function performed by the element for the purpose of carrying out the invention.

Connected

[0112] Similarly, it is to be noticed that the term connected, when used in the claims, should not be interpreted as being limitative to direct connections only. Thus, the scope of the expression a device A connected to a device B should not be limited to devices or systems wherein an output of device A is directly connected to an input of device B. It means that there exists a path between an output of A and an input of B which may be a path including other devices or means. “Connected” may mean that two or more elements are either in direct physical or electrical contact, or that two or more elements are not in direct contact with each other but yet still co-operate or interact with each other.

Embodiments

[0113] Reference throughout this specification to *"one embodiment"*, *"an embodiment"*, *"one arrangement"* or *"an arrangement"* means that a particular feature, structure or characteristic described in connection with the embodiment/arrangement is included in at least one embodiment/arrangement of the present invention. Thus, appearances of the phrases *"in one embodiment/arrangement"* or *"in an embodiment/arrangement"* in various places throughout this specification are not necessarily all referring to the same embodiment/arrangement, but may. Furthermore, the particular features, structures or characteristics may be combined in any suitable manner, as would be apparent to one of ordinary skill in the art from this disclosure, in one or more embodiments/arrangements.

[0114] Similarly it should be appreciated that in the above description of example embodiments/arrangements of the invention, various features of the invention are sometimes grouped together in a single embodiment/arrangement, figure, or description thereof for the purpose of streamlining the disclosure and aiding in the understanding of one or more of the various inventive aspects. This method of disclosure, however, is not to be interpreted as reflecting an intention that the claimed invention requires more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive aspects lie in less than all features of a single foregoing disclosed embodiment/arrangement. Thus, the claims following the Detailed Description are hereby expressly incorporated into this Detailed Description, with each claim standing on its own as a separate embodiment/arrangement of this invention.

[0115] Furthermore, while some embodiments/arrangements described herein include some but not other features included in other embodiments/arrangements, combinations of features of different embodiments/arrangements are meant to be within the scope of the invention, and form different embodiments/arrangements, as would be understood by those in the art. For example, in the following claims, any of the claimed embodiments/arrangements can be used in any combination.

Specific Details

[0116] In the description provided herein, numerous specific details are set forth. However, it is understood that embodiments of the invention may be practiced without these specific details. In other instances, well-known methods, structures and techniques have not been shown in detail in order not to obscure an understanding of this description.

Terminology

[0117] In describing the preferred embodiment of the invention illustrated in the drawings, specific terminology will be resorted to for the sake of clarity. However, the invention is not intended to be limited to the specific terms so selected, and it is to be understood that each specific term includes all technical equivalents which operate in a similar manner to accomplish a similar technical purpose. Terms such as *"forward"*, *"rearward"*, *"radially"*, *"peripherally"*, *"upwardly"*, *"downwardly"*, and the like are used as words of convenience to provide reference points and are not to be construed as limiting terms.

Different Instances of Objects

[0118] As used herein, unless otherwise specified the use of the ordinal adjectives *"first"*, *"second"*, *"third"*, etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

Scope of Invention

[0119] Thus, while there has been described what are believed to be the preferred arrangements of the invention, those skilled in the art will recognize that other and further modifications may be made thereto without departing from the spirit of the invention, and it is intended to claim all such changes and modifications as fall within the scope of the invention. Functionality may be added or deleted from the block diagrams and operations may be interchanged among functional blocks. Steps may be added or deleted to methods described within the scope of the present invention.

[0120] Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

Industrial Applicability

[0121] It will be appreciated that the methods/apparatus/devices/systems described/illustrated above at least substantially provide methods and systems for real-time or near-real-time in-line sampling and analysis of particulate matter flowing through a particle transport pipe.

[0122] Thus, while there has been described what are believed to be the preferred embodiments of the invention, those skilled in the art will recognise that other and further modifications may be made thereto without departing from the spirit of the invention, and it is intended to claim all such changes and modifications as fall within the scope of the invention. For example, any formulas given above are merely representative of procedures that may be used. Functionality may be added or deleted from the block diagrams and operations may be interchanged among functional blocks. Steps may be added or deleted to methods described within the scope of the present invention.

[0123] The systems and methods described herein, and/or shown in the drawings, are presented by way of example only and are not limiting as to the scope of the invention. Unless otherwise specifically stated, individual aspects and components of the systems and methods may be modified, or may have been substituted, therefore known equivalents, or as yet unknown substitutes such as may be developed in the future or such as may be found to be acceptable substitutes in the future. The systems and methods described herein may also be modified for a variety of applications while remaining within the scope and spirit of the claimed invention, since the range of potential applications is great, and since it is intended that the present systems and methods be adaptable to many such variations.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A system for in-line sampling of particulate matter, comprising:

a frame adapted to sealingly engage with a particulate matter transport pipe, the frame comprising:

a sample ledge adapted to protrude into the pipe to receive and accumulate particulate matter flowing through the pipe;

a housing adapted to receive a sampling device;

an inspection window located within, or adjacent to, the sample ledge;

a gas inlet port adapted to receive and transport a jet of gas; and

a gas outlet port adapted to direct the jet of gas to flow across the sample ledge so as to clear accumulated particulate matter from the sample ledge.

2. A system as claimed in Claim 1 further comprising:

an optical source for emitting optical radiation through the inspection window;

an optical detector adapted to detect optical radiation reflected from the accumulated particulate matter through the inspection window.

3. A system as claimed in Claim 2 wherein the optical source is a narrow linewidth optical source.

4. A system as claimed in Claim 2 wherein the optical source is a broadband optical source.

5. A system as claimed in Claim 2 wherein the optical source is a near-infrared optical source.

6. A system as claimed in Claim 2 wherein the optical source is a visible optical source.

7. A system as claimed in Claim 2 wherein the optical source is a far-infrared optical source.

8. A system as claimed in Claim 2 wherein the optical source is an ultraviolet optical source.

9. A system as claimed in any one of Claims 2 to 8, wherein the optical source is a tunable optical source.

10. A system as claimed in any one of the preceding claims further comprising a processor for controlling: the optical source; receiving and analysing optical signals detected by the detector; and initiating a jet of gas to clear accumulated particulate matter from the sample ledge.

11. A system as claimed in claim 10 wherein the processor is configured to execute program instructions for:

irradiating particulate matter accumulated on the sample ledge with optical radiation generated by the optical source;

monitoring reflected optical radiation from accumulated particulate matter on the sample ledge to determine the optical density of the accumulated particulate matter;

determining when the optical density of the accumulated particulate matter is the equivalent of infinite optical density;

measuring one or more attributes of the accumulated particulate matter from the reflected optical radiation received by the optical detector; and

activating a jet of gas to be directed from the gas outlet port across the sample ledge to clear the accumulated particulate matter from the sample ledge.

12. A system as claimed in any one of the preceding claims, wherein the optical source is adapted to illuminate particulate matter accumulated on the sample ledge.

13. A system as claimed in any one of the preceding claims, wherein the detector is adapted to measure reflected light from the accumulated particulate matter.

14. A system as claimed in any one of the preceding claims, wherein the detector is adapted to measure spectral information of light reflected from the accumulated particulate matter.

15. A system as claimed in any one of the preceding claims, wherein the detector is adapted to measure absorption information of light reflected from the accumulated particulate matter.

16. A system as claimed in any one of the preceding claims, wherein the detector is adapted to measure transmission information of light reflected from the accumulated particulate matter.

17. A system as claimed in either Claim 1 or Claim 2, wherein the frame comprises upper and lower sealing lips adapted to engage with a wall of the pipe thereby to seal the pipe when the frame is installed therein.

18. A system as claimed in any one of the preceding claims, wherein the inspection window comprises an optically transparent inspection window adapted to permit optical inspection using the sampling device of particulate matter accumulated on the sample ledge.

19. A system as claimed in any one of the preceding claims, wherein the gas inlet port is connected to a compressed gas source.

20. A system as claimed in Claim 4 wherein the compressed gas is an inert gas or air.

21. A system as claimed in Claim 4, wherein the compressed gas is air.

22. A system as claimed in either Claim 20 or Claim 21, wherein the compressed gas has a pressure of between about 100 kPa to about 1000kPa.

23. A system as claimed in Claim 22, wherein the compressed gas has a pressure of between about 200 kPa to about 800k Pa.

24. A system as claimed in any one of the preceding claims wherein the frame is installed in a pipe with a slope angle of between about 0° to about 80° to the vertical.

25. A system as claimed in any one of the preceding claims, wherein the sample device comprises:

a processor comprising program instructions for:

irradiating particulate matter accumulated on the sample ledge with optical radiation generated by the optical source;

monitoring reflected optical radiation from accumulated particulate matter on the sample ledge to determine the optical density of the accumulated particulate matter;

determining when the optical density of the accumulated particulate matter is the equivalent of infinite optical density;

measuring one or more attributes of the accumulated particulate matter from the reflected optical radiation received by the optical detector; and activating a jet of gas to be directed from the gas outlet port across the sample ledge to clear the accumulated particulate matter from the sample ledge.

26. A method for in-line sampling of particulate matter, comprising the steps of:

providing a frame adapted to sealingly engage with a particulate matter transport pipe, the frame comprising:

a sample ledge adapted to protrude into the pipe to receive and accumulate particulate matter flowing through the pipe;

a housing adapted to receive a sampling device;

an inspection window located within, or adjacent to, the sample ledge;

a gas inlet port adapted to receive and transport a jet of gas; and

a gas outlet port adapted to direct the jet of gas to flow across the sample ledge so as to clear accumulated particulate matter from the sample ledge;

providing a sampling device comprising an optical source and an optical detector;

irradiating particulate matter accumulated on the sample ledge with optical radiation generated by the optical source;

monitoring reflected optical radiation from accumulated particulate matter on the sample ledge to determine the optical density of the accumulated particulate matter;

determining when the optical density of the accumulated particulate matter is the equivalent of infinite optical density;

measuring one or more attributes of the accumulated particulate matter from the reflected optical radiation received by the optical detector; and

activating a jet of gas to be directed from the gas outlet port across the sample ledge to clear the accumulated particulate matter from the sample ledge.

27. A method as claimed in Claim 26, wherein the inspection window comprises an optically transparent inspection window adapted to permit optical inspection using the sampling device of particulate matter accumulated on the sample ledge.

28. A method as claimed in either Claim 26 or Claim 27, wherein the gas inlet port is connected to a compressed gas source.

29. A method as claimed in any one of Claims 26 to 28, wherein the optical density of the accumulated particulate matter on the sample ledge is measured in real-time or near-real-time.

30. A method as claimed in any one of Claims 26 to 29, wherein the one or more parameters of the accumulated particulate matter on the sample ledge is measured in real-time or near-real-time.

31. A kit for a system for in-line sampling of particulate matter, the kit comprising:

an electronic module comprising:

an optical source; and

an optical detector;

an electronic module comprising:

a processor;

a memory; and

a communication module;

a pneumatic module adapted for clearing samples of the particulate off a ledge;

a curved face plate for in-line attachment of the optical, electronic and pneumatic modules to a pipe wherein the curved faceplate is provided in a plurality of options suitable to attach the system to a pipe of a size matching the selected face plate; and

a ledge module configured to connect to the face plate such that, when connected, the ledge is located within the pipe to receive particulate matter flowing through the pipe when in use;

wherein the ledge module is provided in a plurality of size and configuration options to suit the slope on the pipe in which the system is to be installed.

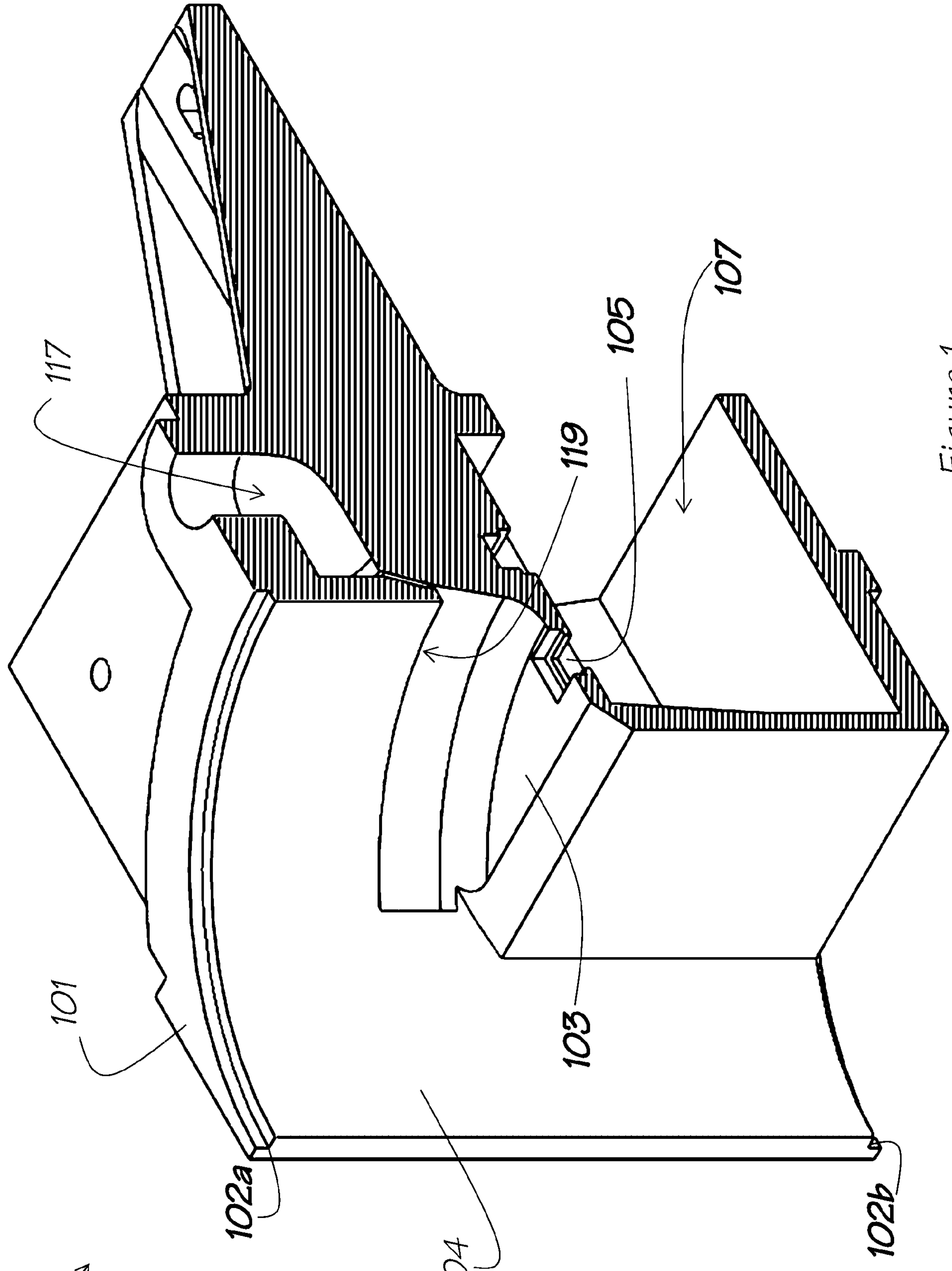

Figure 1

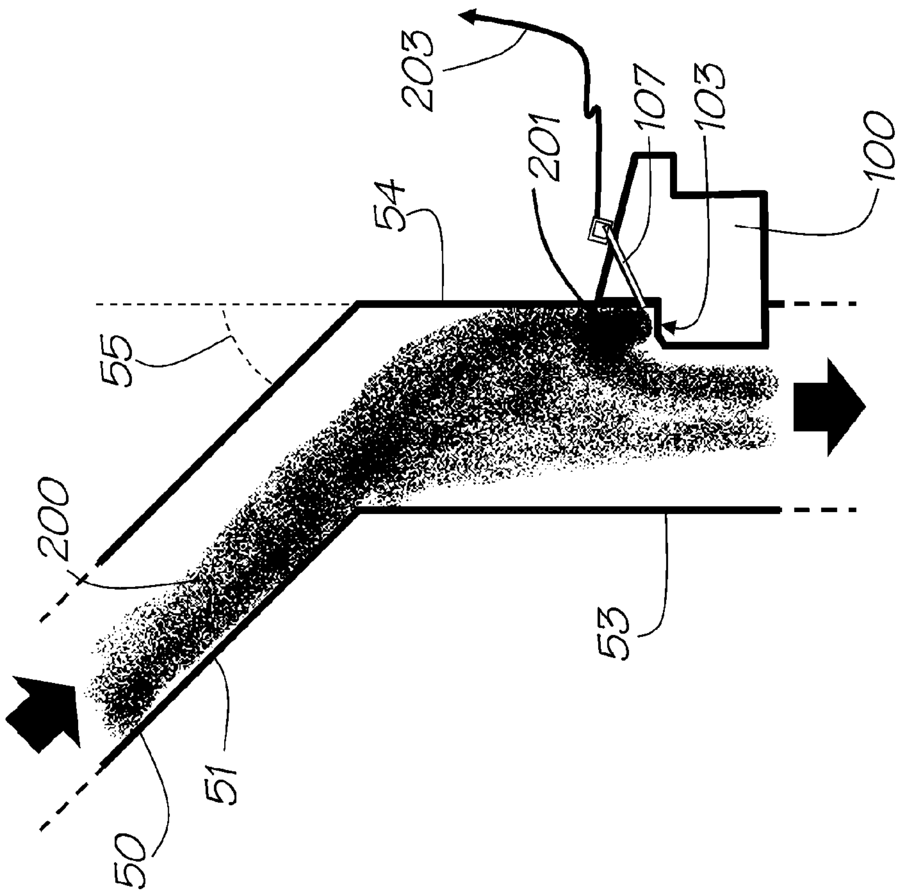

Figure 3

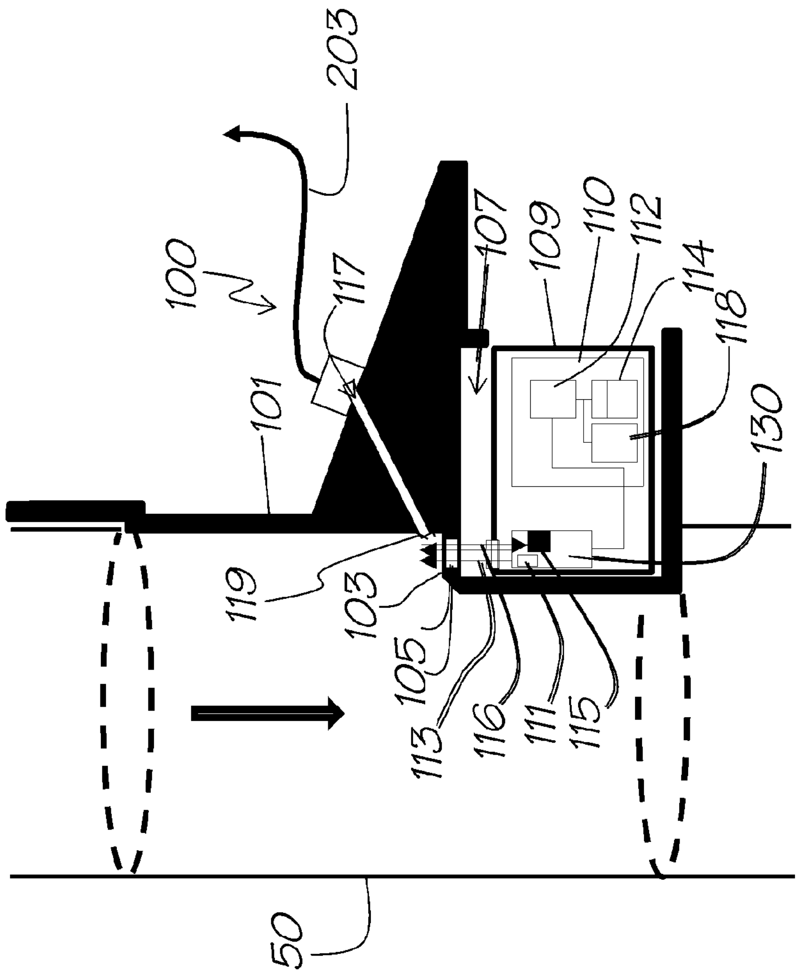

Figure 2

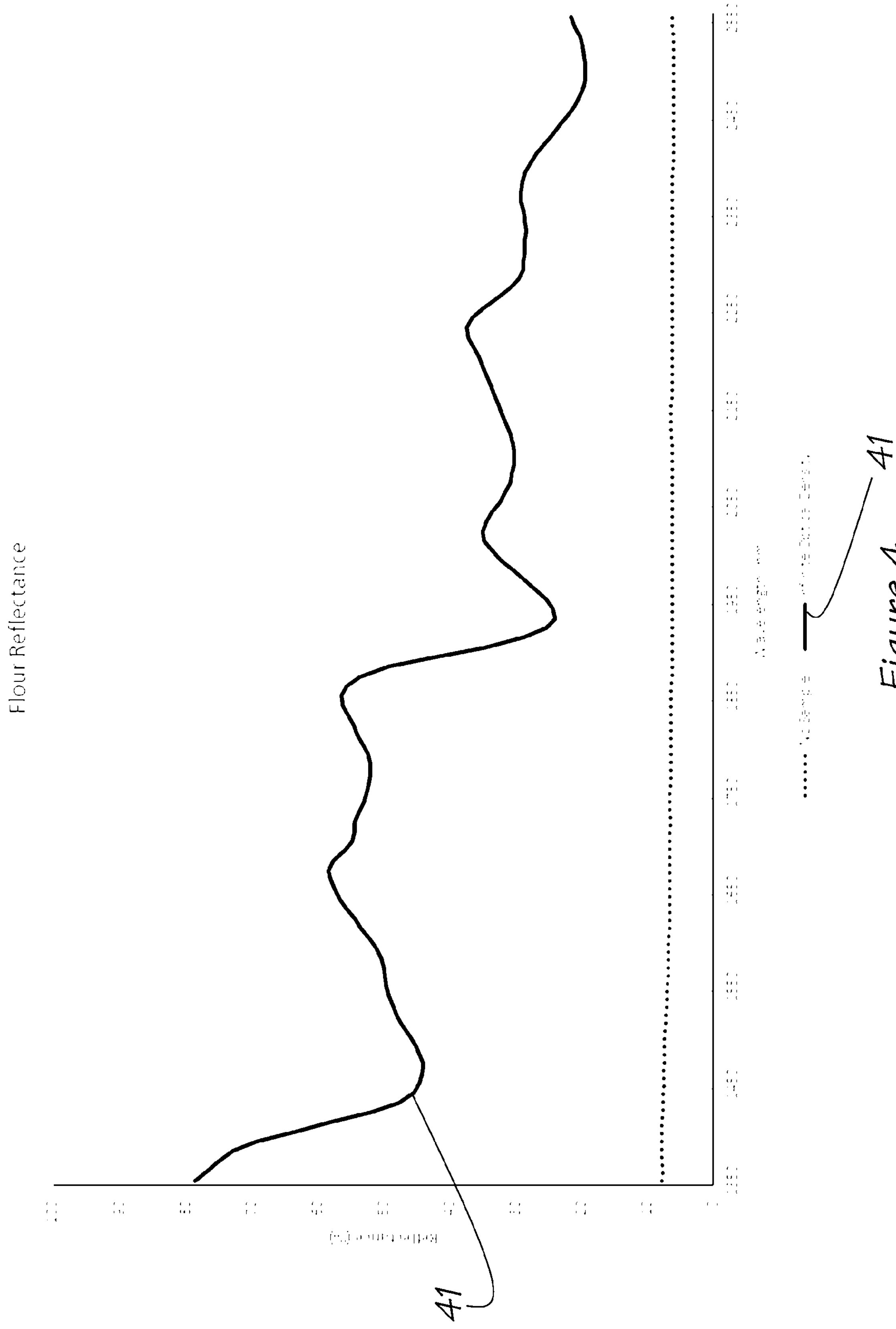

Figure 4

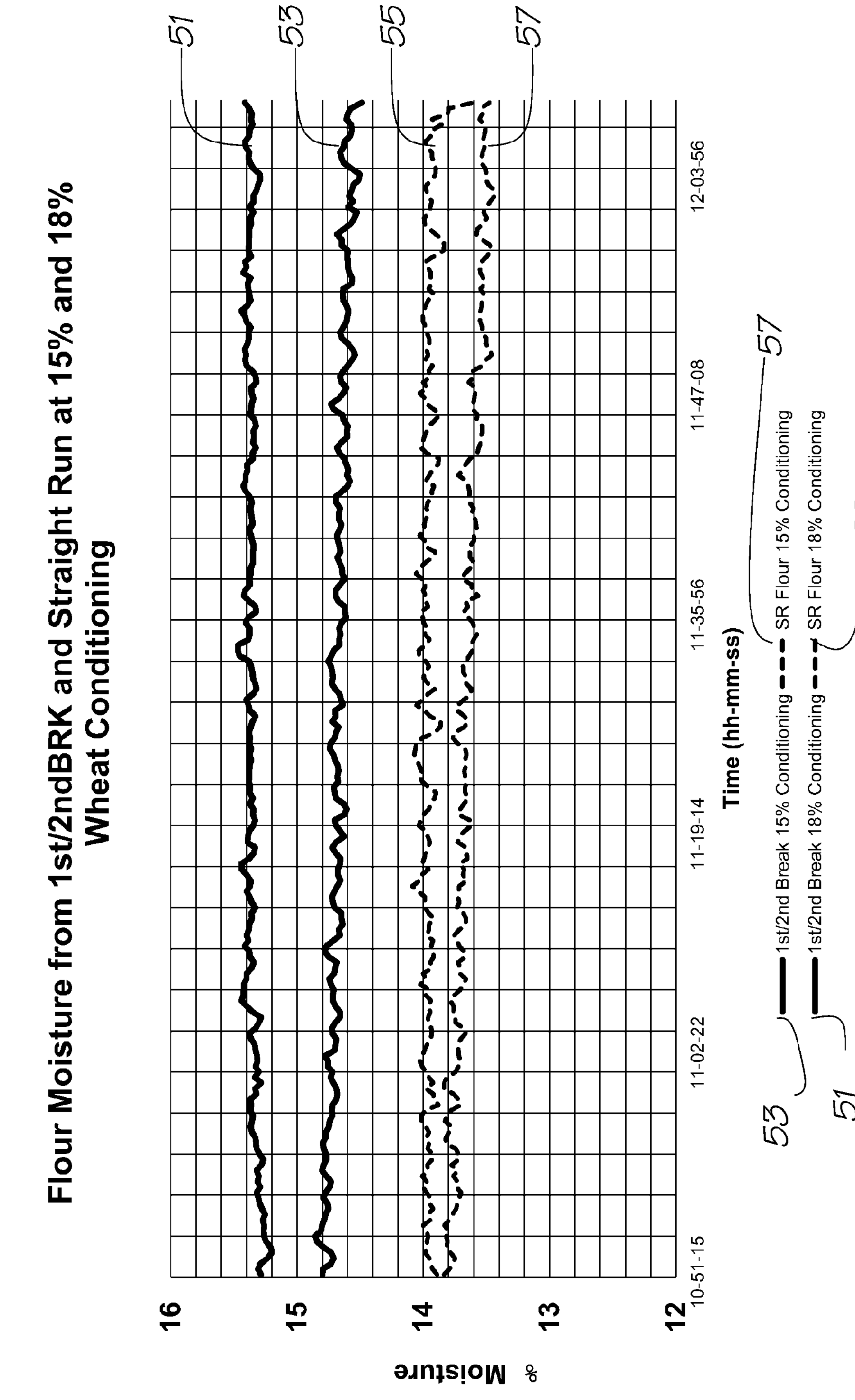
Flour Moisture from 1st/2ndBRK and Straight Run at 15% and 18% Wheat Conditioning
% Moisture
16
15
14
13
12
10-51-15
11-02-22
11-19-14
11-35-56
11-47-08
12-03-56
Time (hh-mm-ss)
51
53
55
57
1st/2nd Break 15% Conditioning
SR Flour 15% Conditioning
1st/2nd Break 18% Conditioning
SR Flour 18% Conditioning

Figure 5

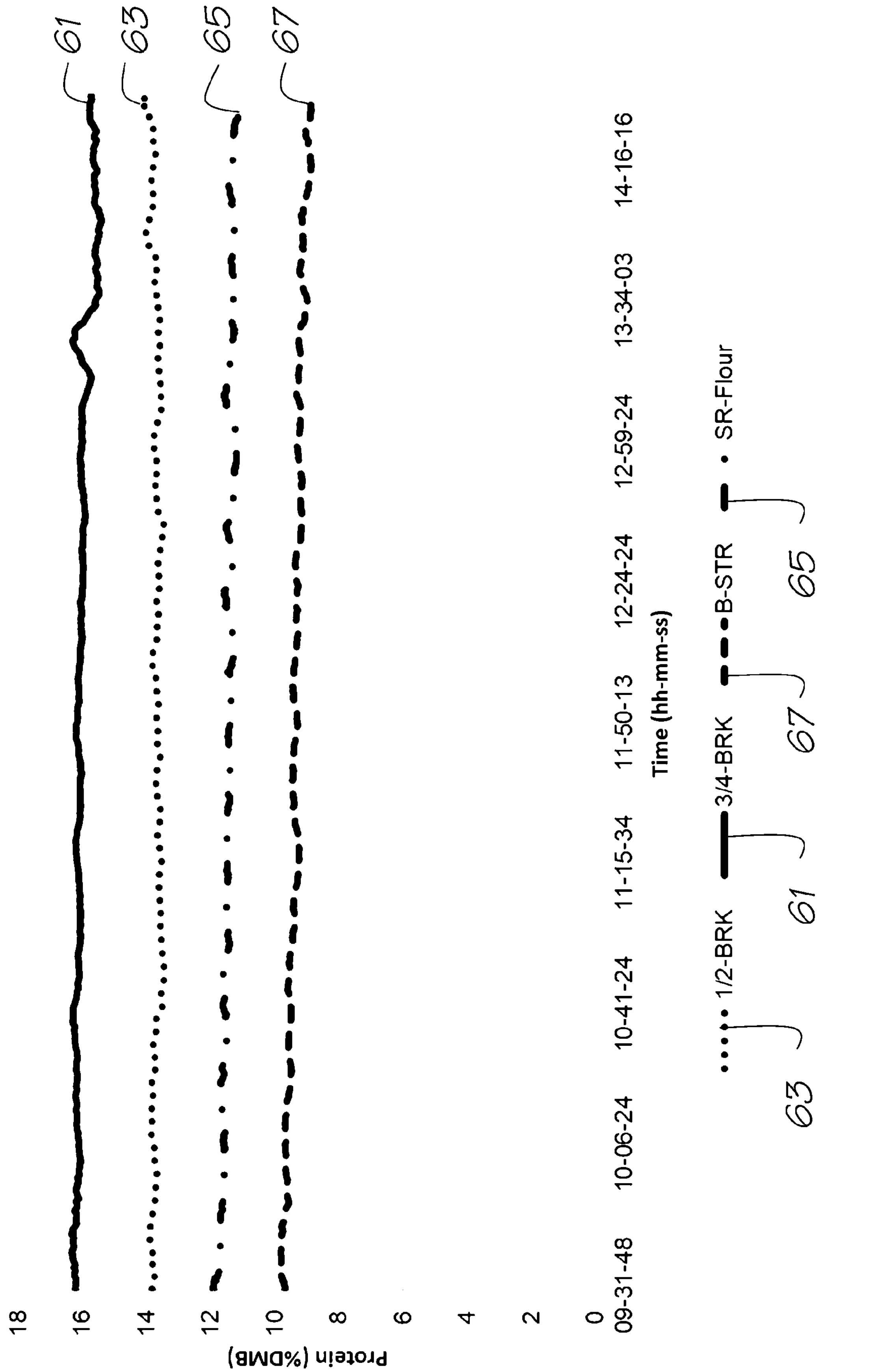
Protein (%DMB)
18
16
14
12
10
8
6
4
2
0
09-31-48
10-06-24
10-41-24
11-15-34
11-50-13
12-24-24
12-59-24
13-34-03
14-16-16
Time (hh-mm-ss)
1/2-BRK
3/4-BRK
B-STR
SR-Flour
61
63
65
67

Figure 6

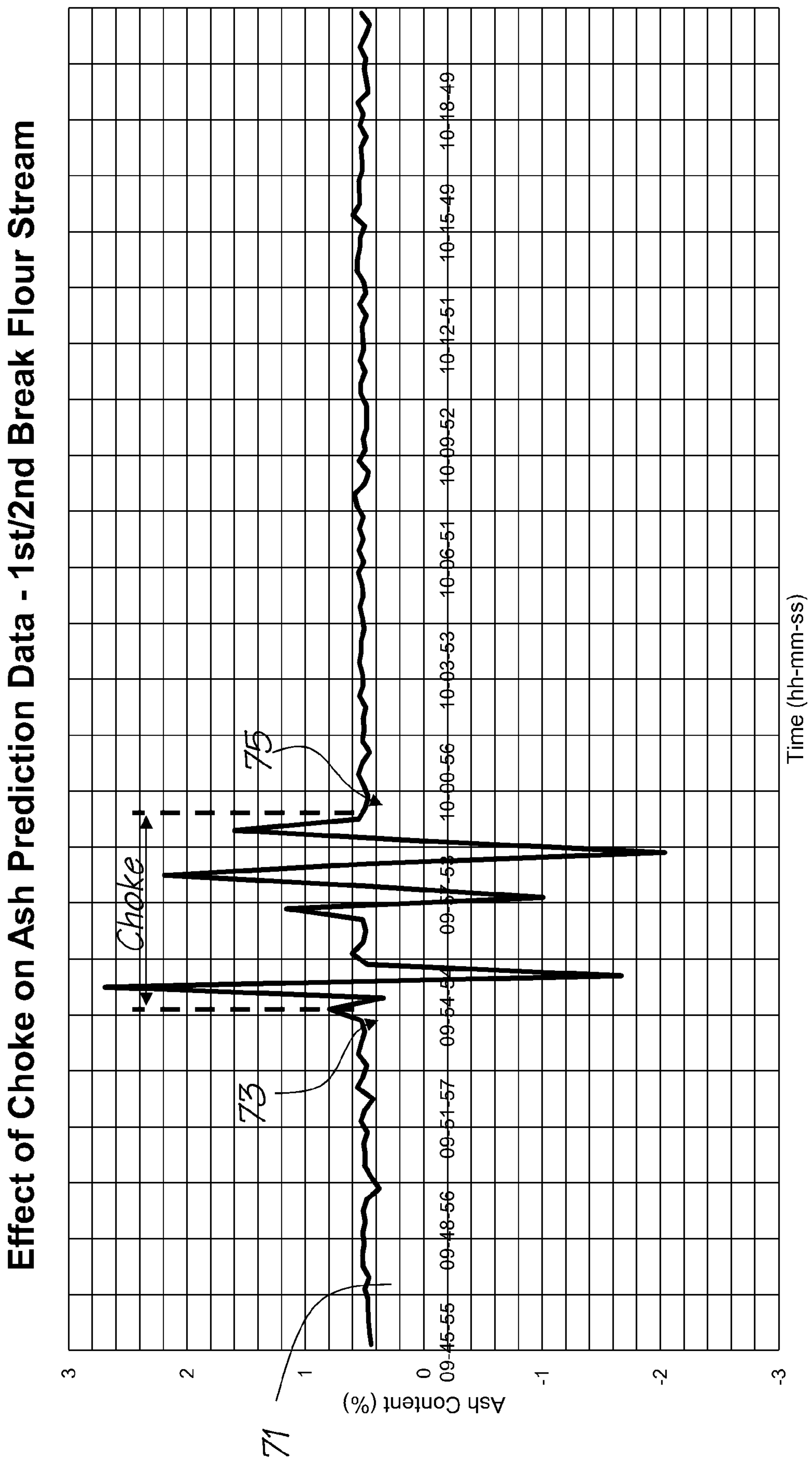
Effect of Choke on Ash Prediction Data - 1st/2nd Break Flour Stream
Ash Content (%)
3
2
1
0
-1
-2
-3
Time (hh-mm-ss)
09-45-55
09-48-56
09-51-57
09-54-54
09-57-53
10-00-56
10-03-53
10-06-51
10-09-52
10-12-51
10-15-49
10-18-49
Choke
71
73
75

Figure 7

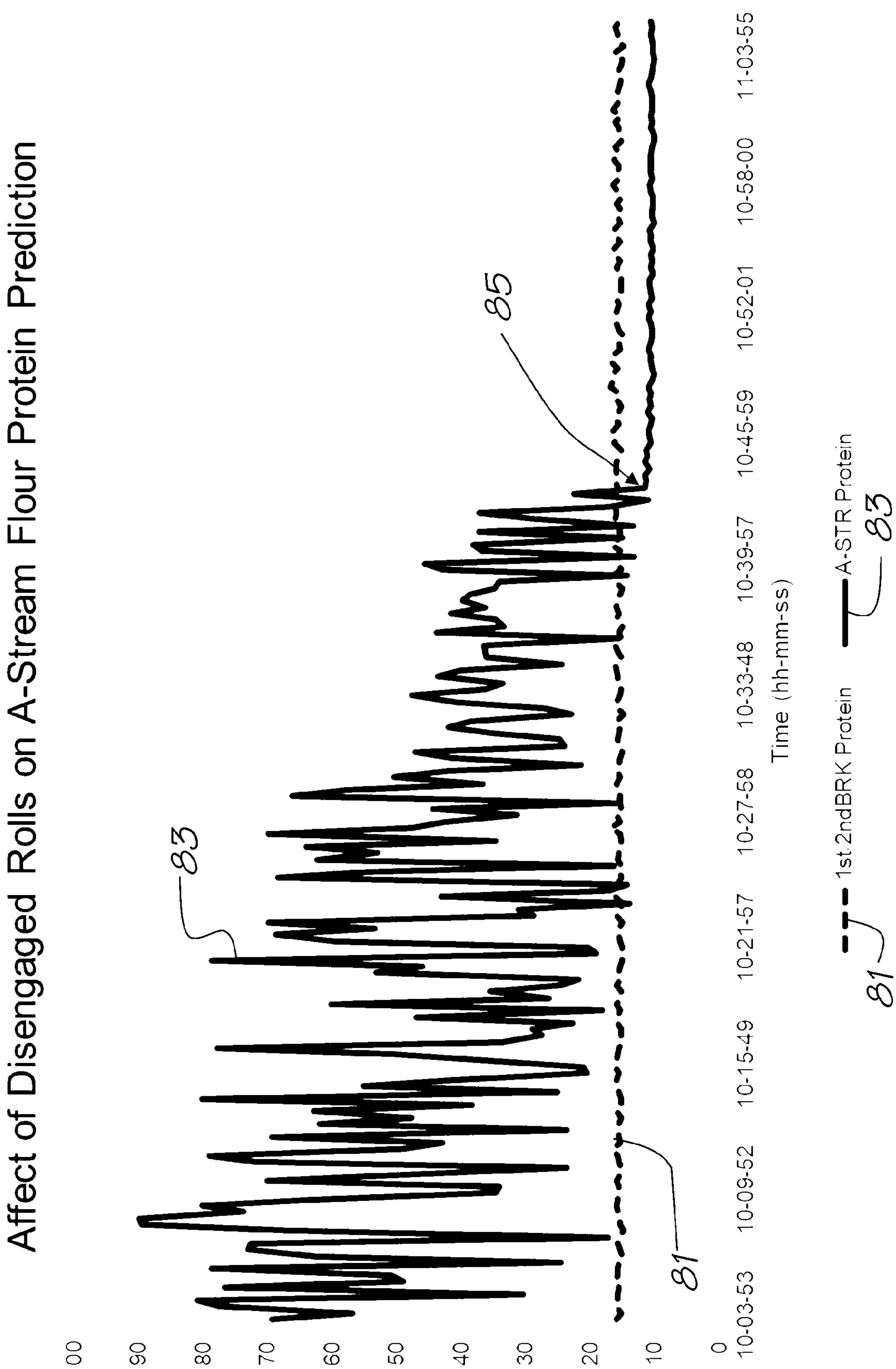
Affect of Disengaged Rolls on A-Stream Flour Protein Prediction
Protein Content (%DMB)
100
90
80
70
60
50
40
30
20
10
0
10-03-53
10-09-52
10-15-49
10-21-57
10-27-58
10-33-48
10-39-57
10-45-59
10-52-01
10-58-00
11-03-55
Time (hh-mm-ss)
83
81
85
1st 2ndBRK Protein
A-STR Protein

Figure 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2021/050257

A. CLASSIFICATION OF SUBJECT MATTER

G01N 1/20 (2006.01) G01N 15/00 (2006.01) G01N 21/01 (2006.01) G01N 21/27 (2006.01) G01N 21/31 (2006.01) G01N 21/33 (2006.01) G01N 21/3563 (2014.01) G01N 21/3581 (2014.01) G01N 21/359 (2014.01) G01N 21/47 (2006.01) G01N 21/55 (2014.01) G01N 21/85 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Database: PATENW (EPODOC, WPIAP and English full text databases). IPC and CPC (including sub-marks where they exist): G01N 1/00; G01N 15/00; G01N 21/00; G01N 1/20. CPC (including sub-marks where they exist): G01N 2001/1018; G01N 2001/1006; G01N 2021/0339; G01N 2021/8592; G01N 2033/0091; G01N 15/0205; . Keywords: particle, particulate, grain, kernel, seed, powder, dust; ledge, shelf, cantilever, sill, horizontal surface; sample, extract, specimen, withdraw, aliquot; collect, accumulate, settle, trap, deposit, cover; pipe, tube, conduit; window, glass; inlet, entrance; outlet, exit; gas, air, nitrogen; jet, stream; remove, blow, expel, clear, discharge; optic, light, radiation, ultraviolet, infrared; source, emit, lamp; LED, laser; sense, detect, inspect, examine, photocell, photodiode, camera, CCD; reflect, scatter; kit; plate, flange; curved; AND LIKE TERMS. Databases: DOCDB and DWPI. Applicant: Australian Export Grains Innovation Centre Limited. Inventor: John Kalitsis, Kenneth James Quail, Daniel Fan Li. Applicant and Inventor names searched in internal databases provided by IP Australia.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 April 2021	19 April 2021

Name and mailing address of the ISA/AU	**Authorised officer**
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustralia.gov.au	Richard Baker AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. +61262832583

INTERNATIONAL SEARCH REPORT

International application No. **PCT/AU2021/050257**

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	US 4154533 A (LEVINE) 15 May 1979	
X	Abstract, column 2 line 45 to column 3 line 29, column 3 line 49 to column 4 line 23, column 7 lines 8 to 15, figures 1, 2, 4 and 5	1-30
A	Abstract, column 2 line 9 to column 7 line 20, figures 1 to 11	31
	JP 2020-101443 A (IHI CORP) 02 July 2020	
X	Abstract, paragraphs 0014 to 0021, 0023, 0024, 0026, 0027, 0044 to 0046, 0053 to 0055, figures 1, 2 and 5	7, 8, 22 (in part), 24 (in part), 31
	JP 2020-101443 A (IHI CORP) 02 July 2020	
P,X	Abstract, paragraphs 0015 to 0021, 0024, 0026 to 0027, 0045, 0053 to 0055 and 0058, figures 1, 2 and 5	1-6, 9-21, 22 (in part), 23, 24 (in part), 25-30

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/AU2021/050257**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document/s Cited in Search Report		**Patent Family Member/s**	
Publication Number	**Publication Date**	**Publication Number**	**Publication Date**
US 4154533 A	15 May 1979	US 4154533 A	15 May 1979
JP 2020-101443 A	02 July 2020	JP 2020101443 A	02 Jul 2020
JP 2020-101443 A	02 July 2020	JP 2020101443 A	02 Jul 2020

End of Annex

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.