



(51) International Patent Classification:

G01L 9/00 (2006.01) G01L 21/00 (2006.01)

G01L 19/12 (2006.01) F04D 15/00 (2006.01)

(21) International Application Number:

PCT/GB2021/053044

(22) International Filing Date:

24 November 2021 (24.11.2021)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

2018638.3 26 November 2020 (26.11.2020) GB

(71) Applicant: EDWARDS LIMITED [GB/GB]; Innovation Drive, Burgess Hill Sussex RH15 9TW (GB).

(72) Inventors: NORRINGTON, Michael John; Edwards Limited, Innovation Drive, Burgess Hill Sussex RH15 9TW (GB). BARLOW, Steven Graham; Edwards Limited, Innovation Drive, Burgess Hill Sussex RH15 9TW (GB).

(74) Agent: ARNOLD, Emily; Edwards Limited, Innovation Drive, Burgess Hill Sussex RH15 9TW (GB).

(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, 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))

(54) Title: PRESSURE SENSING UNIT, VACUUM SYSTEM AND METHOD

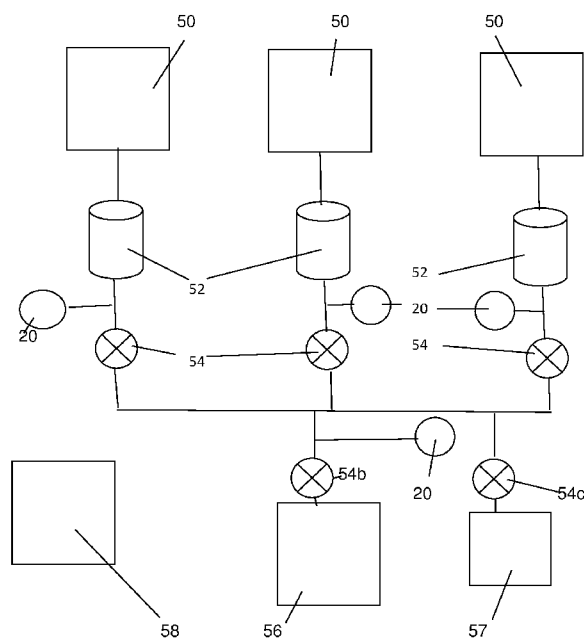


Figure 5

(57) Abstract: A pressure sensing unit, vacuum system and method are disclosed. The pressure sensing unit comprises: an inlet for connecting to a system to be monitored; a sensor configured to detect pressure, the sensor being in fluid communication with the inlet and determining circuitry configured to receive signals indicative of the detected pressure from the sensor. The determining circuitry is configured to determine a pressure and a rate of change of pressure over time from the signals. The determining circuitry comprises an output for outputting signals indicative of the determined pressure and the rate of change of pressure.



PRESSURE SENSING UNIT, VACUUM SYSTEM AND METHOD

FIELD OF THE INVENTION

The field of the invention relates to a pressure sensing unit, a vacuum system
5 including such a unit and a method of monitoring a vacuum system using a pressure sensing unit.

BACKGROUND

Pressure sensing units such as pressure gauges that measure the pressure in a
10 system are known. These may have different forms, but in some examples are formed as capacitance manometers with two parallel conductive plates, one of which is flexible. An inlet to the capacitance manometer allows a gas to enter the sensing unit between the plates, so that changes in pressure distorts the flexible plate and changes the distance and therefore the capacitance between the
15 plates. Measuring the capacitance between the plates therefore provides an indication of pressure and the sensing unit may output a signal indicative of the capacitance and thus, pressure detected.

In some cases the pressure sensing unit may be configured to detect a threshold
20 pressure and to output a signal when this pressure is reached.

Many semiconductor processing chambers operate under vacuum conditions. The pressure within the processing chambers will vary during the processing operations and the pressure, changes in pressure and rate of change in pressure
25 are indicative of the process being performed.

It would be desirable to provide a pressure sensing unit able to sense and detect characteristic pressure changes.

30 SUMMARY

A first aspect provides a pressure sensing unit comprising: an inlet for connecting to a system to be monitored; a sensor configured to detect pressure, said sensor

- 2 -

being in fluid communication with said inlet; determining circuitry configured to receive signals indicative of said detected pressure from said sensor and to determine a pressure and a rate of change of pressure over time from said signals; said determining circuitry comprising an output for outputting signals
5 indicative of said determined pressure and said rate of change of pressure.

It was recognised that absolute pressure and rate of change of pressure may both be important indicators of a state and activity of a system being monitored. Providing a pressure sensing unit that can determine and indicate both allows for
10 a robust, responsive and informative unit, that can provide indications relevant to a system locally and promptly.

Although pressure sensing units able to detect pressure are known, providing the additional local capability of determining rate of change in pressure, allows
15 information characteristic of the system being monitored to be collected and determined at the point of monitoring, allowing for a more robust and responsive system with fewer delays than were the calculations to be performed at a remote central processor.

20 In some embodiments, said pressure sensing unit further comprises: a data store for storing data indicative of at least one pressure characteristic representative of at least one of a state and an activity of said system being monitored; said determining circuitry being configured to compare said detected pressure and rate of change of pressure with said stored data and to output a signal in
25 response thereto.

The pressure sensing unit may further comprise a data store that may store data indicative of one or more pressure characteristics of the system that the pressure sensing unit is monitoring. These pressure characteristics include pressure and
30 rate of change of pressure and are representative of particular predetermined states and/or activities of the system being monitored. Storing this data within the unit and providing the determining circuitry with comparison capabilities,

- 3 -

allows the sensing unit to determine when or if the state and/or activity of the system indicated by such pressure characteristics has occurred. Where a match between the measured pressure characteristics and the stored data is detected a signal indicating that the state and/or activity has been detected is output.

5

In some embodiments, at least one of said at least one stored pressure characteristics comprises threshold values, said threshold values comprising at least one pressure value and at least one rate of change in pressure value.

- 10 Although the pressure characteristics can be stored in a number of ways. They may for example be stored as a pressure versus time waveform and pattern matching techniques may be used to match the characteristics, in some embodiments at least one of said at least one stored pressure characteristics comprises a plurality of threshold values, said threshold values comprising at
15 least one pressure value and at least one rate of change in pressure value.

In some embodiments, said determining circuitry is configured to output a signal indicating detection of said at least one pressure characteristic in response to said determining circuitry determining that said detected pressure and rate of
20 change of pressure matches said stored data associated with said at least one pressure characteristic.

In some embodiments, said detected pressure and rate of change in pressure is determined to match said at least one pressure characteristic when said detected
25 values pass said stored threshold values.

One computationally simple way of storing and comparing pressure characteristics is to store threshold values and to determine when the monitored value passes the threshold values. In this regard, depending what is being
30 monitored the property either exceeding or falling below the threshold value may be indicative that the characteristic is present.

- 4 -

In some embodiments, said determining circuitry is configured to monitor said pressure to determine when said at least one pressure threshold value is passed and thereupon to initiate monitoring of said rate of change in pressure.

5

In some cases, the pressure characteristics may be determined by detecting the pressure passing a threshold value and then increasing or decreasing at a rate that is higher than a further threshold level. This may for example be the case where the predetermined process is a process gas flow transition, where the pressure passing one value and then changing at a rate that is greater than a further value is indicative of a change in the process gas flow.. The rate of change in pressure may be detected over a short time period, said time period being less than 1 second, in some embodiments less than 50 ms. Having a pressure sensing unit configured to determine values locally allows for a reactive sensor that is fast acting. Where rate of change in pressure is detected this is done over a very short time period to maintain this reactive characteristic.

20

In some embodiments, said pressure sensing unit comprises an interface to providing access to said data store.

It may be advantageous to be able to update the data store so that the characteristics monitored for may be set, updated or changed to be applicable to a particular system that is to be monitored and a particular state or activity that a user is interested in. Such an interface allows the pressure sensing unit to be calibrated for a particular system, whereby predetermined operations can be performed on the system, pressure characteristics measured by the pressure sensing unit and then stored in the data store. During normal operation the pressure characteristics measured can be compared with the stored values and signals output where there is a match the signals indicating that the predetermined operations have been detected. The interface may also allow the pressure characteristics to be updated as a system is changed or ages, such that accuracy in detecting the predetermined state or activity is maintained.

- 5 -

In some embodiments, said pressure sensor comprises a capacitance manometer.

- 5 Although the pressure sensor may have a number of forms, capacitance manometers are particularly effective. Capacitance manometers operate on the principle of diaphragm deflection and such deflection is proportional to force (pressure), and thus, independent of the composition of the gas being measured. Thus, a capacitance manometer's output doesn't change if the gas
- 10 composition in the process changes. In many semiconductor processes the chemistry can change on a second-by-second basis such that a pressure sensor that measures pressure independently of gas type is very advantageous. Furthermore, capacitance manometers operate effectively across a very wide pressure range.

15

In some embodiments, said pressure sensor unit comprises an interface for outputting said signals indicative of said determined pressure and said rate of change of pressure.

- 20 In some cases the pressure sensor unit may have an interface that may be wired or wireless, for channelling output signals to some central control system or directly to a component in a system such as a valve that may be controlled by these signals. In this way the detected change and rate of change in pressure can be used in the control of a system such as a vacuum system. Where the
- 25 signals are channelled directly to a component rather than via control circuitry the system's response to a detected change in conditions may be almost immediate.

- A second aspect provides a vacuum system comprising at least one vacuum pump for evacuating a vacuum chamber, at least one valve and at least one
- 30 pressure sensing unit according to a first aspect.

- 6 -

In some embodiments, said vacuum system further comprises: control circuitry configured to receive signals output from said at least one pressure sensing unit and in response to said signals to control at least one of said at least one vacuum pump and said at least one valve.

5

Pressure sensing units according to embodiments are particularly applicable for vacuum systems used in semiconductor processing. During semiconductor processing the processes being performed in the vacuum chambers being evacuated by the vacuum pumping system are often controlled independently to the vacuum pumping system, such that the pumping system is not aware of what the processes being performed are. Providing appropriate control of the vacuum pumping system when operations within the process chamber are unknown can be challenging. Providing pressure sensing units with determining circuitry for determining both the pressure and the rate of change of pressure allows the pressure characteristics of the system to be determined and the activity and/or state in the chamber to be inferred. Furthermore, in such systems a pressure sensor will always be reacting to events that have occurred. Providing a sensor where pressure and rate of change of pressure can be determined locally allows the determination to be done quickly allowing signals that may be used to control the system to be generated without undue delay.

10
15
20

In some embodiments the pressure sensor unit comprises an interface for channelling signals output from said pressure sensing unit to at least one of said at least one valve, said at least one valve being configured to receive and be controlled by signals output via said interface of said pressure sensing unit.

25

In some embodiments, the signals output by the pressure sensing unit in response to a pressure threshold being passed, and a rate of change in pressure threshold being passed may be channelled via an interface to at least one of the valves rather than via control circuitry. This provides a very responsive system where control of the valve can be almost immediate following the pressure sensing unit detecting certain conditions. It may be important in certain systems

30

- 7 -

that a valve is opened or closed when certain conditions change. Being able to do this almost immediately may help protect the system and/or improve system performance.

- 5 In some embodiments, the pressure sensing unit comprises a data store storing pressure characteristics indicative of certain conditions or activities within the vacuum chamber and this allows the pressure sensing unit to output signals to the central control circuitry indicative of these activities or states which in turn allows the central control circuitry to control the vacuum system accordingly,
- 10 allowing the system to operate efficiently and effectively. For example, a process gas flow transition may be detected and valves opened and closed at appropriate moments to both protect the pumps and to make the pumping process more efficient. In this regard, some process gases may be incompatible with some of the components of the vacuum system. For example, they may be
- 15 corrosive, flammable, toxic or have a propensity to deposit by-products, and it may be preferable for certain pumps or other parts within the system to be protected from these gases. Where changes in pressure and/or rate of changes in pressure are an indication of a process gas flow transition then detection of this by the pressure sensing unit can be used to trigger a control signal to promptly
- 20 control the required valves and divert the process gas flow appropriately.

In some embodiments, said control circuitry comprises a user interface configured to receive a user input, said user input being configured to communicate with said interface of at least said one pressure sensing unit.

25

- The control circuitry associated with the vacuum system may have a user interface that is able to communicate with the interfaces on each of the at least one pressure sensing unit. Where the vacuum system is a complex system with multiple pumps and valves, there may be multiple pressure sensing units and
- 30 providing a central way of updating the data stores of these pressure sensing units allows the system to be effectively and efficiently calibrated.

- 8 -

A third aspect provides a method of monitoring a vacuum system using a pressure sensing unit according to a first aspect, the method comprising: attaching said pressure sensing unit to said vacuum system; monitoring said
5 vacuum system during operation of said vacuum system and comparing detected pressure and rate of change of pressure with stored pressure characteristic data; and in response to said step of comparing indicating a match outputting a signal indicating said pressure characteristic has been detected.

- 10 In some embodiments, said method further comprises the initial steps of: calibrating said pressure sensing unit by: operating said vacuum system to perform at least one predetermined process; monitoring said vacuum system to determine pressure characteristics of said system during said predetermined process; storing said measured pressure characteristics in said data store; and
15 during operation in response to said step of comparing indicating a match with said stored measured pressure characteristics outputting a signal indicating said predetermined process is occurring in said vacuum system.

As noted earlier, when evacuating vacuum chambers in for example,
20 semiconductor processing fabs the processes occurring within the chambers may not be transparent to the vacuum pumping system and thus, providing appropriate and timely control for the pumps and valves may be challenging. Having a pressure sensing unit that can both monitor pressure and rate of change of pressure and can compare these monitored pressure characteristics to
25 stored values that are representative of particular states and/or activities within the system, allows the system to respond quickly and appropriately to changes in the processes performed within the vacuum chambers and allows for effective and prompt control of the system.

- 30 Further particular and preferred aspects are set out in the accompanying independent and dependent claims. Features of the dependent claims may be

- 9 -

combined with features of the independent claims as appropriate, and in combinations other than those explicitly set out in the claims.

Where an apparatus feature is described as being operable to provide a function,
5 it will be appreciated that this includes an apparatus feature which provides that function or which is adapted or configured to provide that function.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will now be described further, with
10 reference to the accompanying drawings, in which:
Figure 1 shows a pressure sensing unit according to an embodiment;
Figure 2 shows the pressure changes characteristic of a pumpdown;
Figure 3 shows steps in a method performed by a pressure sensing unit detecting pumpdown;
15 Figure 4a shows steps performed in a method of calibrating a pressure sensing unit for a particular vacuum system according to an embodiment;
Figure 4b shows steps performed in a method for monitoring a vacuum system using a pressure sensing unit according to an embodiment; and
Figure 5 shows a vacuum system according to an embodiment.

20

DESCRIPTION OF THE EMBODIMENTS

Before discussing the embodiments in any more detail, first an overview will be provided.

25 Pressure gauges such as capacitance manometers that measure the pressure within systems are known. Capacitance manometers are pressure gauges that are widely used in vacuum systems for the semiconductor and related industries. Such gauges allow the detection of changes in pressure and allow the pumps and valves to be controlled accordingly. In such systems there may be multiple
30 pressure gauges and a central control unit that collects the pressure readings from the multiple gauges within the system and analyses the readings centrally to determine the operation of the system and provide appropriate control. This

- 10 -

central analysis and control has an associated time delay between collecting results and providing the analysis and also carries the risk of a central failure which would have a devastating effect on the system.

- 5 Embodiments provide individual sensing units which have their own processing circuitry for detecting and determining not only pressure values but also the rate of change in values, allowing characteristic pressures and pressure changes to be detected and correlated with certain processes occurring within the vacuum system. The circuitry or logic within the pressure sensing units may be
- 10 programmable logic such as a programmable logic controller, such that the determining steps may be set, changed or updated. The system may also comprise a data store for storing data relating to characteristic pressure changes for a system being monitored along with the events and/or activities that such pressure characteristics signify.

- 15 In this way, individual pressure sensing units can identify characteristic pressure changes and output signals indicating that a certain event such as a process gas flow transition or a pumpdown is occurring. Vacuum systems evacuating semiconductor processing systems may require a pumpdown detection and/or
- 20 process gas flow transition capability in order to appropriately control the vacuum system components. The signals output by the pressure sensing units can be received by a central control unit for a vacuum system allowing components such as valves and pumping units to be controlled in response to determining that certain events are occurring within the processing system being evacuated. In
- 25 other embodiments interface circuitry may be used to channel signals from the pressure sensing unit(s) to at least one of the controllable components such as one of the valves. This output signal may be used to control the component directly and in this way latency within the system may be further reduced.

- 30 Individual pressure sensing units can be calibrated and the calibration updated to make the units aligned with a particular system and to reflect changes in the system as the system is changed or ages.

- 11 -

Figure 1 shows a pressure sensing unit according to an embodiment. The pressure sensing unit 30 comprises a housing having an inlet 10 that in use is placed in fluid communication with the vacuum system to be monitored. In this
5 embodiment, the pressure sensing unit 20 has a pressure sensor in the form of a capacitance manometer which comprises two conductive electrode plates one of the conductive electrode plates 22 being flexible. Although in this embodiment the pressure sensor is a capacitance manometer, other types of pressure sensor may be used.

10

Gas entering the inlet 10 will change the pressure within the capacitance manometer and flexible plate 22 will deflect. This will change the capacitance between the two conductive plates and this changing capacitance is measured by sensor 24. Sensor 24 transmits a signal indicative of the change of capacitance
15 to determining circuitry 30 which determines the pressure that this change in capacitance signifies and also determines the rate of change in that pressure over time. This information can be output via interface 40. Interface 40 may be a wired connection to a central control unit or it may comprise a wireless connection. It may also, as noted above be a connection for channelling output
20 signals directly to one of the components to be controlled, rather than via a central control unit. Interface 40, may in some embodiments comprise a user interface allowing a user to access information in the pressure sensing unit.

Determining circuitry 30 has a data store 32 associated with it. Data store 32
25 stores pressure characteristics of the system being evacuated and determining circuitry 30 will compare the pressure measured and the changes in pressure with these pressure characteristics and thereby identify an activity and/ or state of the system being evacuated.

30 The data in the data store 32 may be updated via interface 40. This may be done in some cases during a calibration phase in which the pressure sensing unit is attached to the system and various processes are performed within the system

- 12 -

and the pressure characteristics measured at the pressure sensor during these processes are detected and stored within data store 32 along with information regarding the process that they relate to. Thus, during later operation of the vacuum system determining circuitry 30 can compare the pressure

5 characteristics measured by the pressure sensor and where they match those in the data store a signal indicating that the corresponding process is being performed can be output.

In this regard, the pressure matching may be a pattern matching algorithm to
10 match changes in pressure over time, with previously detected changes in pressure or it may be a more simple technique where threshold values are compared to measured values and rates and the result of the comparison used to determine whether a particular process is being performed or not.

15 The signals output may be sent to a central control unit which may receive signals from multiple pressure sensing units and control components within the vacuum system on the basis of these signals. In some embodiments, the central control unit may itself comprise analysing logic configured to perform more complex analysis on the signals received than is performed on the sensing units.
20 For example, where pattern matching techniques may be used to determine a pressure characteristic, a simple version of these techniques may be performed on the sensing unit itself and/or more complex analysis on the central controller.

Figure 2 shows an example of how chamber pumpdown is detected using
25 threshold values stored within data store 32 of the pressure sensing unit 20. The threshold values indicative of pumpdown in this example are an absolute value P_t and a rate of change threshold value. During normal operation shown on the lefthand side of the figure there are small variations in pressure over time. At time t_0 a threshold pressure P_t , that is stored in data store 32, is detected as
30 being passed and in response to this determining circuitry 30 starts monitoring the rate of change of pressure over the following predetermined time period t_1-t_0 . A pumpdown event is recognised to have occurred where the change in pressure

- 13 -

$P_1 - P_t$ during the predetermined time period $t_1 - t_0$, the predetermined time period being less than 1 second, and in some cases less than 50ms, is determined to be greater than a predetermined value. This is a computationally simple comparison and allows the sensing unit to detect chamber pumpdown locally at the sensing unit itself as it occurs. The sensing unit can then output a signal indicating pumpdown is occurring and this signal may be transmitted to a central control circuit which controls the valves and the pumps within the vacuum pumping system.

- 10 Figure 3 shows a flow diagram illustrating steps in a method of operating a vacuum system that is being sensed by a pressure sensing unit according to an embodiment. Initially in step S10 the vacuum system is operated with the pressure sensing unit attached. The pressure sensing unit will detect the pressure and rate of change in pressure at a point in the system. The
- 15 determining circuitry in the pressure sensing unit determines if the detected pressure is above a threshold value at step D5 and it will continue to do this until the threshold value is detected. In this embodiment, it is exceeding the pressure threshold value that triggers the next step. In other embodiments where a different process is being detected it may be the monitored pressure value falling
- 20 below the threshold value that triggers the next step. The next step occurs at D15 where it is determined if the rate in change in pressure over the following predetermined time period is greater than a threshold value. If it is, this is indicative in this example of pumpdown occurring and thus, at step S20 a signal is output to indicate this. If at D15 the rate of change in pressure is determined
- 25 not to be greater than the threshold value during the predetermined time, then no signal is output and the pressure sensing unit continues to monitor the system.

- Figure 4A shows steps occurring in a method of calibrating the pressure sensing unit when it is attached to a particular vacuum system. One advantage of the
- 30 pressure sensing unit of the embodiment is that it has an interface that allows access to the determining circuitry 30 and data store 32. In some embodiments, the determining circuitry is programmable. This allows flexibility in the conditions

- 14 -

the pressure sensing unit is configured to detect and also allows its accuracy and relevance to a particular system to be maintained.

5 In the first step of the calibration S100 the pressure sensing unit is attached to the vacuum system and at step S110 the predetermined operation or operations that the sensing unit is to detect are performed. The sensing unit measures and stores the pressure characteristics at step S120 that are representative of these predetermined operations in the data store of the sensing unit. The sensing unit is then calibrated for these operations.

10

Figure 4B shows the operation of the vacuum system with the newly calibrated pressure sensing unit attached to it. Thus, at step S200 the vacuum system is operated and at step S210 the measured pressure characteristics are compared with the stored pressure characteristics, at step D205 it is determined if the
15 measured pressure characteristics match the stored pressure characteristics and if they don't the comparison and measuring steps continue. If they do then at step S220 a signal is output indicating a predetermined process corresponding to the measured pressure characteristics has been detected. This signal may be transmitted to a central control unit for the vacuum system, which will control the
20 components of the system such as pumps and valves to operate in a way appropriate to the process that has been detected.

The system will continue to operate and pressure characteristics will be detected and compared with stored values and signals output as different processes are
25 detected.

Figure 5 shows a vacuum system according to an embodiment. The system comprises a plurality of semiconductor processing chambers 50. These are evacuated by the vacuum system. The vacuum system has a high vacuum pump
30 52 which may be a turbomolecular pump connected to each chamber and a pressure sensing unit 20 measuring the pressure in the line connecting the exhaust of each high vacuum pump 52 to one of two backing pumps 56 or 57.

- 15 -

There are valves 54 for isolating the high vacuum pumps 52 and chambers 50 from the backing pumps 56 and 57. Two of the valves 54b and 54c isolate individual backing pumps 56 or 57 respectively. Control of valves 54b and 54c allows the backing pump that is currently operational and backing the high vacuum pump to be switched. This may be advantageous where some of the process gas is corrosive and one of the backing pumps 56 is not resistant to the corrosive gas. Being able to switch between backing pumps when it is determined that the corrosive gas is to be output protects the backing pump 56 from damage.

10

In this embodiment, there is a further pressure sensing unit 20 for measuring the pressure and rate of change in pressure in the line connecting the backing pump 56 to the high vacuum pumps 52. There is a central control unit 58 for controlling the vacuum system. In this embodiment, the central control unit 58 receives signals from the different pressure sensing units 20, these signals being indicative of pressure characteristics of the system that have been detected, and in response the central control unit 58 generates transmits and control signals to control the operation of valves 54, 54b, 54c and pumps 52, 56 and 57. In other embodiments, the pressure sensing units 20 are configured to output their output signals directly to the corresponding valve, either via a wired connection, or wirelessly. The signals output from the pressure sensing unit act as control signals controlling the corresponding valve to open or close. In this way direct control of the valves can be performed from the pressure sensing unit 20 without the need for the signals to be sent via a central control unit. This allows not only for a simpler system, but also and perhaps more importantly for a system that is quicker to respond to changes in conditions, allowing the system to react with speed to any detected changes.

20

25

30

Figure 5 is one example of a vacuum system and it should be understood that other configurations of valves, pumps and sensing units may be provided.

- 16 -

Although illustrative embodiments of the invention have been disclosed in detail herein, with reference to the accompanying drawings, it is understood that the invention is not limited to the precise embodiment and that various changes and modifications can be effected therein by one skilled in the art without departing
5 from the scope of the invention as defined by the appended claims and their equivalents.

- 17 -

REFERENCE SIGNS

	10	inlet
	20	pressure sensing unit
	22	flexible conductive plate
5	24	capacitance detector
	30	determining circuitry
	32	data store
	40	input/output interface
	50	vacuum chamber
10	52	vacuum pump
	54, 54b, 54c	valve
	56, 57	backing pump
	58	central control logic

CLAIMS

1. A pressure sensing unit comprising:
an inlet for connecting to a system to be monitored;
5 a sensor configured to detect pressure, said sensor being in fluid communication with said inlet;
determining circuitry configured to receive signals indicative of said detected pressure from said sensor and to determine a pressure and a rate of change of pressure over time from said signals;
10 said determining circuitry comprising an output for outputting signals indicative of said determined pressure and said rate of change of pressure.
2. A pressure sensing unit according to claim 1, said pressure sensing unit further comprising:
15 a data store for storing data indicative of at least one pressure characteristic representative of at least one of a state and an activity of said system being monitored;
said determining circuitry being configured to compare said detected pressure and rate of change of pressure with said stored data and to output a
20 signal in response thereto.
3. A pressure sensing unit according to claim 2, wherein at least one of said at least one stored pressure characteristics comprises threshold values, said threshold values comprising at least one pressure value and at least one rate of
25 change in pressure value.
4. A pressure sensing unit according to any one of claims 2 or 3, wherein said determining circuitry is configured to output a signal indicating detection of said at least one pressure characteristic in response to said determining circuitry
30 determining that said detected pressure and rate of change of pressure matches said stored data indicative of said at least one pressure characteristic.

5. A pressure sensing unit according to claim 3 and 4, wherein said detected pressure and rate of change of pressure is determined to match said at least one pressure characteristic when said detected values pass said stored threshold values.

5

6. A pressure sensing unit according to claim 3, or claim 4 or 5 when dependent upon claim 3, wherein said determining circuitry is configured to monitor said pressure to determine when said at least one pressure threshold value is passed and thereupon to initiate monitoring of said rate of change in pressure.

10

7. A pressure sensing unit according to any one of claims 2 to 6, said pressure sensing unit comprising a user interface for accessing and updating said data store.

15

8. A pressure sensing unit according to any preceding claim, wherein said pressure sensor comprises a capacitance manometer.

20

9. A pressure sensor unit according to any preceding claim, said pressure sensor unit comprising an interface for outputting said signals indicative of said determined pressure and said rate of change of pressure.

10. A vacuum system comprising at least one vacuum pump for evacuating a vacuum chamber, at least one valve and at least one pressure sensing unit according to any preceding claim.

25

11. A vacuum system according to claim 10, said vacuum system further comprising:

control circuitry configured to receive signals output from said at least one pressure sensing unit and in response to said signals to control at least one of said at least one vacuum pump and at least one valve.

30

- 20 -

12. A vacuum system according to claim 10 or 11, comprising a pressure sensor unit according to claim 9, said at least one valve being configured to receive and be controlled by signals output via said interface of said pressure sensing unit..

5

13. A method of monitoring a vacuum system using a pressure sensing unit according to any one of claims 1 to 9, comprising:

attaching said pressure sensing unit to said vacuum system;

monitoring said vacuum system during operation of said vacuum system

10 and comparing detected pressure and rate of change of pressure with stored pressure characteristic data; and

in response to said step of comparing indicating a match outputting a signal indicating said pressure characteristic has been detected.

15 14. A method of monitoring said vacuum system according to claim 13, said method further comprising initial steps of:

calibrating said pressure sensing unit by:

operating said vacuum system to perform at least one predetermined process;

20 monitoring said vacuum system to determine pressure

characteristics of said system during said predetermined process;

storing said measured pressure characteristics in said data store;

and

25 during operation in response to said step of comparing indicating a match with said stored measured pressure characteristics outputting a signal indicating said predetermined process is occurring in said vacuum system.

1/4

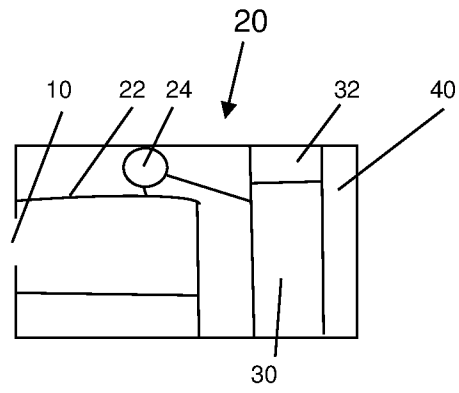


Figure 1

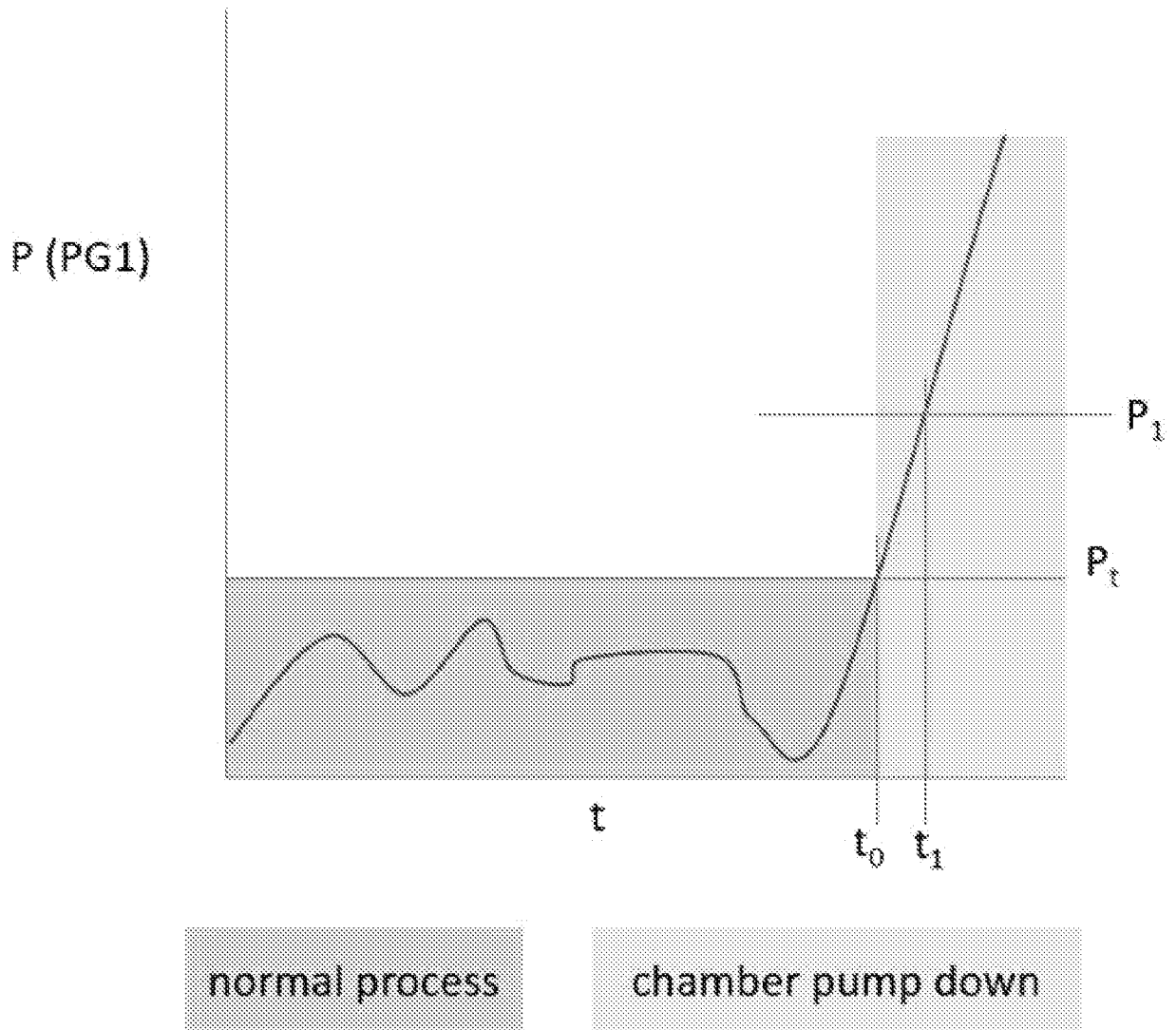
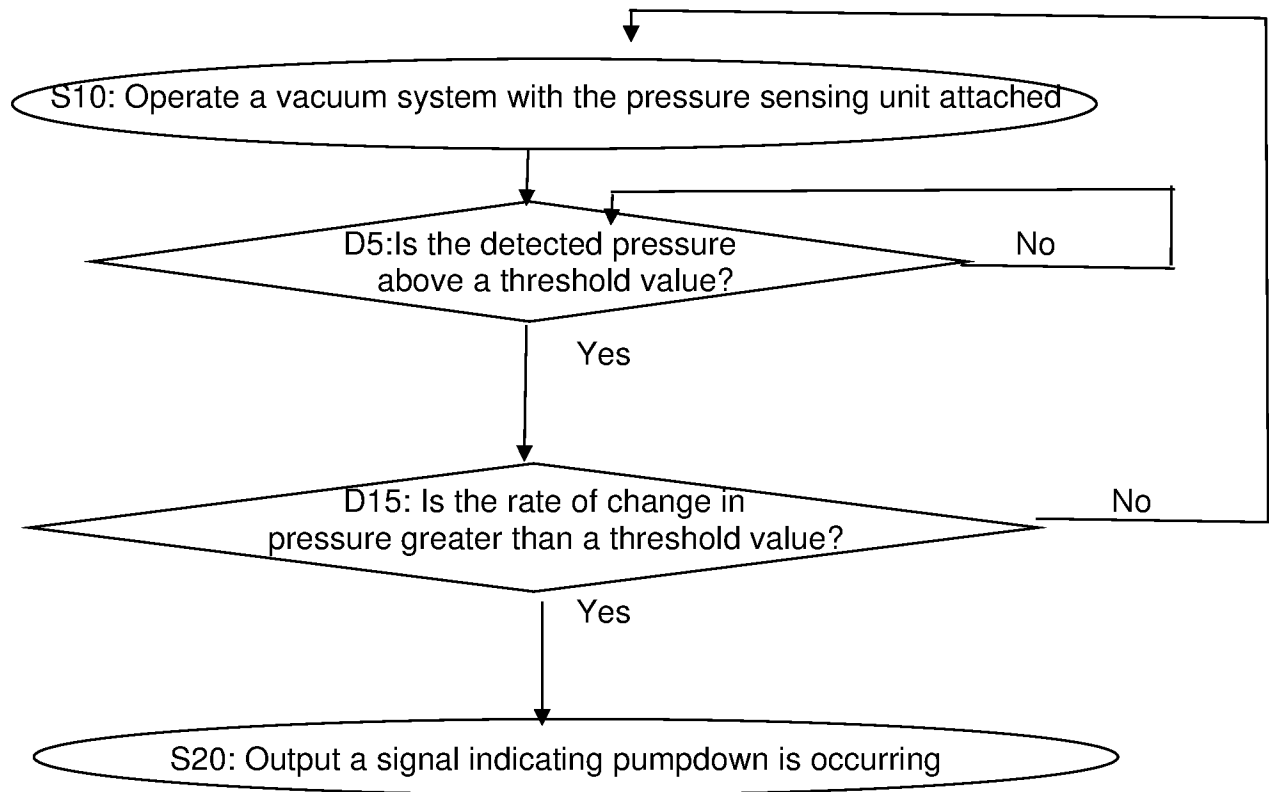
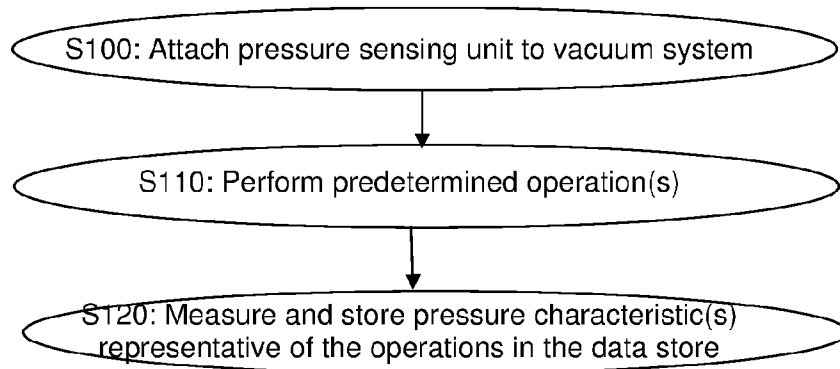
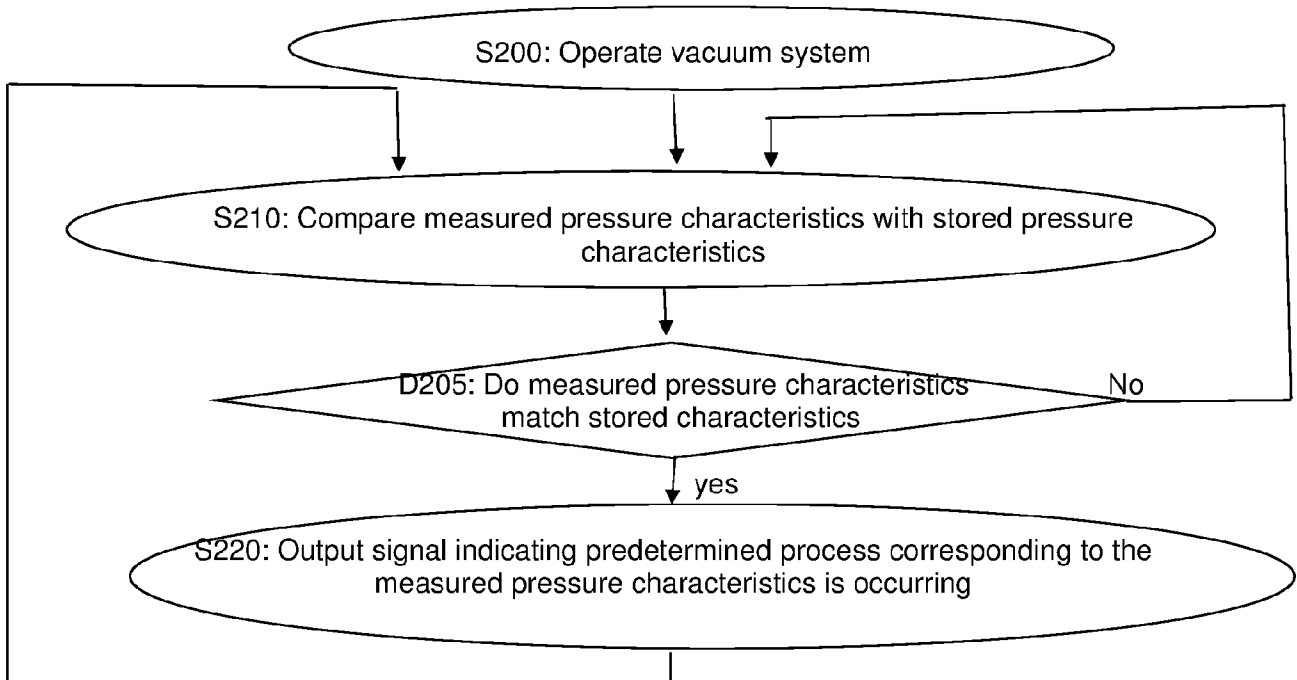


Figure 2

Figure 3

Figure 4AFigure 4B

4/4

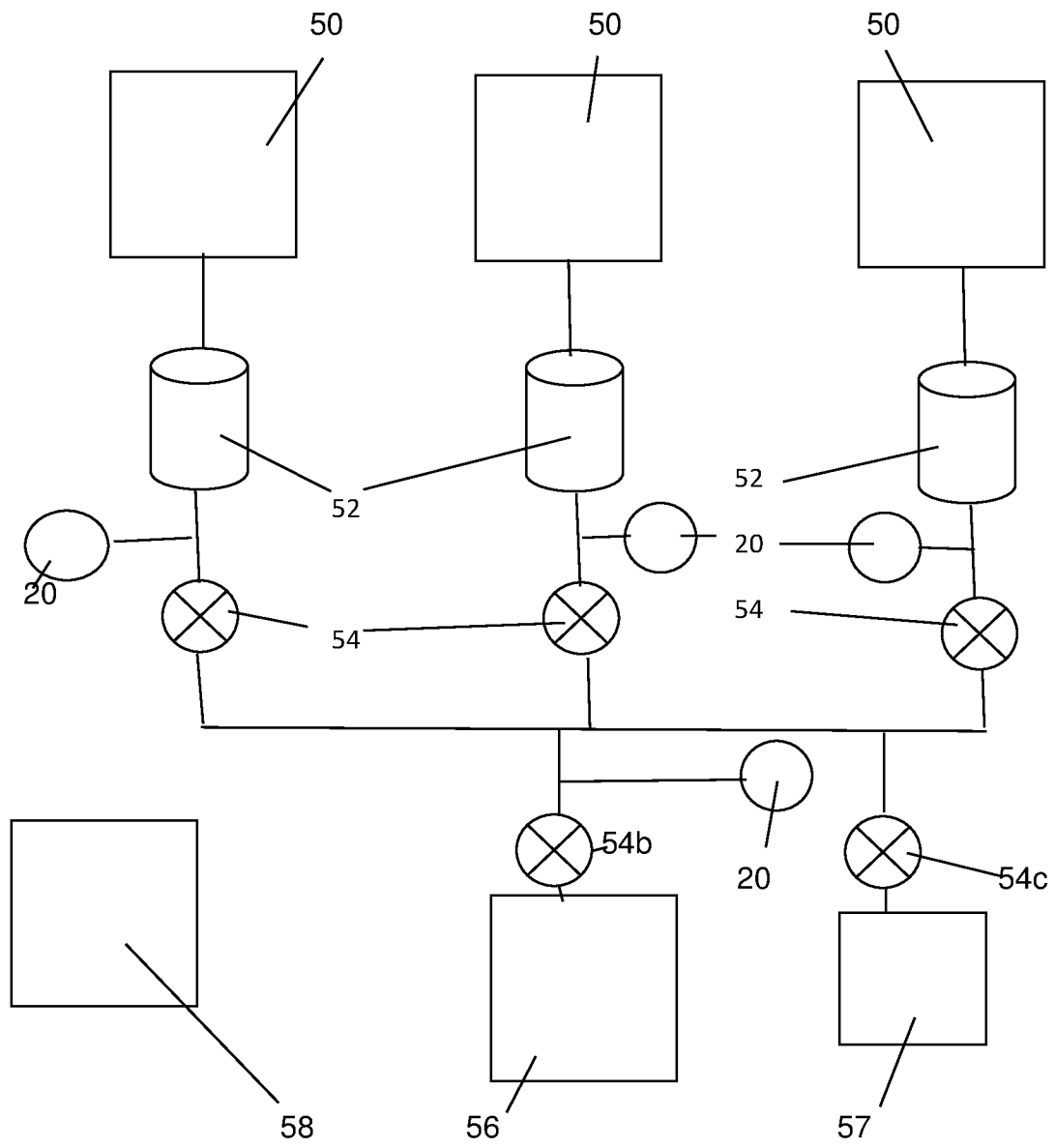


Figure 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2021/053044

A. CLASSIFICATION OF SUBJECT MATTER INV. G01L9/00 G01L19/12 G01L21/00 F04D15/00 ADD.		
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) G01L F04D		
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) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2017/089786 A1 (WILLCOX CHARLES RAY [US] ET AL) 30 March 2017 (2017-03-30) abstract paragraphs [0027], [0054], [0056] figure 14 -----	1-14
X	US 4 018 088 A (MCARTHUR BILLY WALTON) 19 April 1977 (1977-04-19) column 3, lines 6-33 -----	1-14
A	WO 2020/188515 A2 (EDWARDS S R O [CZ]) 24 September 2020 (2020-09-24) abstract page 6, line 19 - page 7, line 6 figure 1 -----	2, 3, 5, 6, 10-14
☐ Further documents are listed in the continuation of Box C. ☒ 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 "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 20 February 2022		Date of mailing of the international search report 28/02/2022
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Grewe, Clemens F.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2021/053044

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2017089786 A1	30-03-2017	CN 106556484 A	05-04-2017
		CN 205785613 U	07-12-2016
		EP 3356778 A1	08-08-2018
		JP 6486555 B2	20-03-2019
		JP 2018526643 A	13-09-2018
		US 2017089786 A1	30-03-2017
		WO 2017058432 A1	06-04-2017

US 4018088 A	19-04-1977	NONE	

WO 2020188515 A2	24-09-2020	CN 113825914 A	21-12-2021
		EP 3942203 A2	26-01-2022
		GB 2582327 A	23-09-2020
		KR 20210138705 A	19-11-2021
		WO 2020188515 A2	24-09-2020
