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"LEAK CHECK ROBOT"
(Abbrebiation: Leak Robo)

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Abstract

Among the areas related to fields of high tech, including the electronics industry and the Production of medical and food products those places requiring a particularly high degree of cleanliness are installing clean rooms. When clean rooms are put into operation for the purpose of assuring a high degree of cleanliness, which is the functional objective of these clean rooms, it is vitally important to measure the volume of dust leakage from the air purification filter. This operation, however, is particularly unpopular with human personnel due to the fact that these operations are preformed high above ground. Due to the foregoing reasons, our company sought to robotize these operations. The robot that we will introduce here is different from the conventional type. We have simplified robot control by providing it with the function to automatically detect the position of the filter that is the object of measurement.

1. Leak Check

The high performance dust removal filter, known as the HEPA, is installed in the air intake of the clean room. Its function is to cut off initially measured contaminated air from the clean room. The degree of cleanliness is largely controlled by the operating capability of this filter and since it determines the performance of the clean room, from the time of delivery of the filters by manufacturers and completion of the plant installation, mandatory measurements of the volume of dust leakage from the filters are taken at fixed time intervals. This measurement is known as a "leak check".

2. The Current situation with Respect to Leak Check Operations and Related Problems

Deterioration of the filter dust removal capacity will result from:

1.) minute scratches on the filter media (glass fiber) that composes the filter or

2.) from an inflow of an exessive amount dust from the filter surface and the surrounding area due to inadequate calking on the installation frame. Consequently, in measurement operations, primary emphasis is placed on precise detection of the influx of dust particles and all leakage points. Normally, leak check operations are performed by two persons. One person moves the sample air intake oriface across the entire surface, at constant speed, while maintaining a level height and fixed distance of normally 2 cm between the filter surface and the sample air intake oriface of the dust counter (purity measurement gauge) (Refer to Fig. 1). The other person ascertains whether there are leaks by reading the indicator on the dust counter.

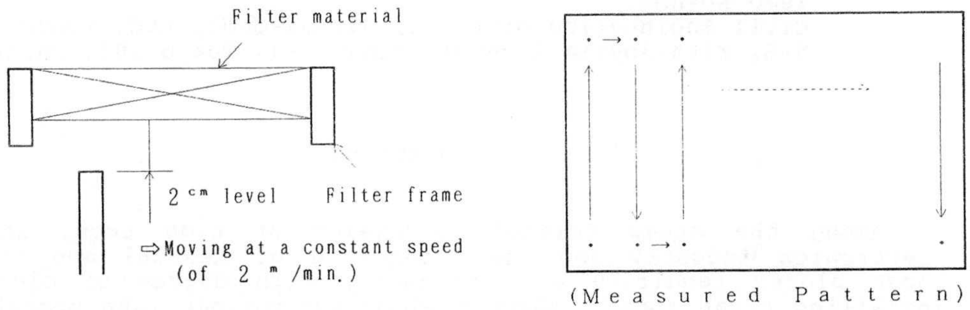


fig-1 Checking for leaks

The following problems occur due to the performance of such hand operations:

1) Normally, the HEPA filter is installed in the ceiling and operations for moving the sample air intake oriface involve a painstaking manuever that requires one to be indifficult position for a long period of time.
2) Becuase of the difficulty of maintaining the distance between the filter surface and the intake vent, or the movement speed of the intake vent, there is scattering due to variations depending on the persons who are taking the measurements. So, measurement precision cannot be attained.
3) No record remains of the movement of the intake oriface in hand operations, and thus it is difficult to get feedback on such things as repair work, because the measurement results and measurement position cannot be verified.

3. Development of the leak check robot

3-1 Basic policies for the design

The basic design was made to conform with the following conditions:
1) Even though installation conditions vary (height of the ceiling, configuration of the filter and installation location), uniform and high quality measurement must be made possible.
2) The system that must be easy to operate and not require any specialized knowledge.
3) It must automatically record the measurement results and measurement position and permit confirmation at any time following the measurement. Among the above conditions, emphasis was placed on simplicity of operations.

Operating and drive instructions for conventional industrial robots are divided into two types; namely, cases where patterns programmed at the time of line design were determined or cases that were executed based on control data that was sent from time to time from the general control computer during the drive. The current situation, however, is one where programming operations will be expanded in order to upgrade operating capability and it will be necessary to achieve a high degree of computer technology. Nevertheless, when we consider introducing robots into the construction industry, it is necessary to perform changes in conditions and constant calculation operations for control data due to the lack of fixed usage conditions. So there are many cases where basic computer knowledge will become a necessary condition. The majority of those engaged in construction on site are not knowledgeable about computers and furthermore, the usage environment is not very favorable.

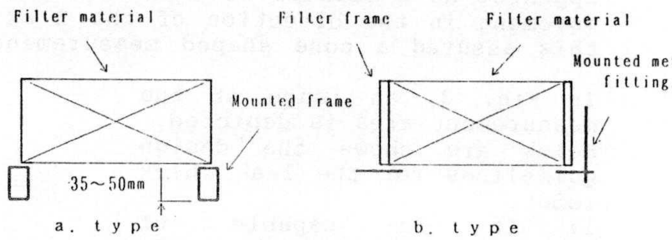


fig. 2 The type of filter being used

In recent years there has appeared a movement in the direction of incorporating decision making functions into the robot itself, but taking the leak check robot as an example, variations in filter dimensions, installation methods, and installation spacing due to laminar flow and turbulance, make it difficult to put operating conditions into patterns, and stepped operations on computers have increased and generalities have substantially decreased.

Thus, we aimed at eliminating prior calculation of control data for measurement operations by the computer by automatically detecting the relative positional relationship between the most essential filters and the robot in order to automate the leak check operation.

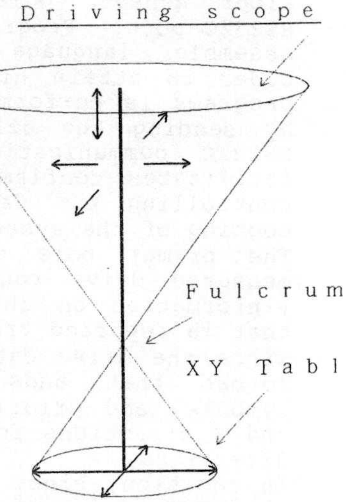


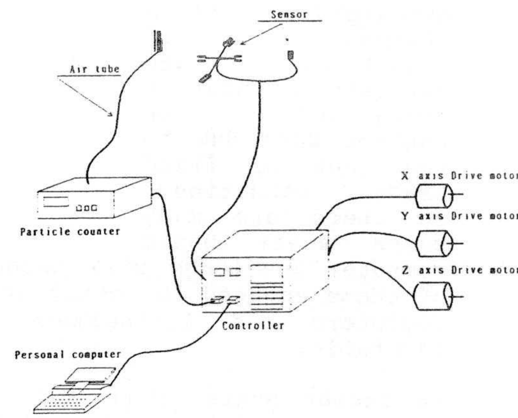
fig. 3 Diagram of driving

In addition, our second basic design emphasis, sought a solution to the cost of introduction that had become an impediment to the introduction of robots into the construction industry. Even with the introduction of high priced robots into on-site construction operations, we could lower the production cost if we could achieve high volume production during fixed periods. The problem, however, is, as mentioned

earlier, that in the construction site the setting of conditions and mobility that vary each time and the production of a robot that met all these functions was expensive and unprofitable and thus could not be developed into practical application.
Consequently, the response to complex operations was made possible by the adoption of a man-machine formula for decisions concerning work conditions. In order to seek simplification and weight reduction in the drive structure, the measurement arm drive was made such that movement of the lower X, Y table of the lower fulcrum appeared as a similar movement in the upper fulcrum and up and down movement in the direction of the Z axis was also made possible and this assured a cone shaped measurement area in the upper fulcrum.

In Fig. 3, an image of the measurement area is depicted.
Below are shown the design guidelines for the leak check robot.

1) It is capable of automatically detecting the relative positional relationship between the filter and robot.
2) The measurement arm is an extendible arm permitting conical drive.
3) The operating decision adopts the man-machine method.
4) The control drive system and controller for measurement data are separated and capable of future extension.



f i g . 4 Diagram of the control system

Fig. 4 shows the system configuration for the control system. The controller controls distance detection information obtained from the reflecting fiber sensor, pulse motor drive and communications through the RS232C port. Programming software for the controller is prepared in assembler language and recorded in the ROM of the controller in order to attain high speed processing. Selection of the recorded programs is performed by a personal computer and the program drives by sending the selected signal to the controller side under the RS232C communications standard. In addition, the pulse motor facilitates confirmation of the amount of change by the drive, by controlling the drive at the target value from the time of the booting of the system.
The primar role of the personal computer is to calculate the measured drive route pattern based upon the absolute information (information on the filter position, etc.) for the stepping motor that is reported from the controller and the entire drive control.
Since the drive data drives the stepping motor, it is sent by data format that adds regular and reverse rotation distinguishing symbols, and priority ranking in the movement in each of the X, Y and Z directions for absolute of movement in each of the X, Y and Z directions.
In addition, since a verification signal is sent from the controller at each step of the drive, by observing the timing of the verification signal at the personal computer, the measurement data by measurement space from the particle couner (clean level measurement device) can be sampled and recorded.

Aside from regular acvitivity information from the reflecting fiber sensor is also monitored and when drive abnormalities or when contract with the filter or structural elements occurs, the drive is automatically shifted into the safe direction.

3-2 Method for Automatic Detection of the Filter Position

In the detection of the position of the filter and the relative position of the robot, the basic condition assumes that the filter installation points will be within the area to be measured by the robot. For the detection of the filter position, we studied the drive patterns that would permit detection of the filter position by laying out the reflecting fiber sensor in "a" position that appears in both the "a" and "b" types of the detection sensor units in Fig. 5. Since there is a level difference between the frame of the filter and the filter surface in the installation condition of the filter as is shown in Fig. 2. We have made it possible to distinguish level differences of both types "a" and "b" by adjusting by sensor the distance detection range with the detection direction of the sensor. For detection of the difference in level between the filter frame and the installation unit, we used the "a"type sensor unit, since the difference is as much as 35 to 50 mm. In this method of detection we made a sensor unit that can detect the position of the side surface (surface joined perpendicularly to the filter surface) of the installation unit frame and trace the surface of the installation frame by moving the boom in a set direction while maintaining a fixed distance from the filter surface (about 10 mm), with one sensor.

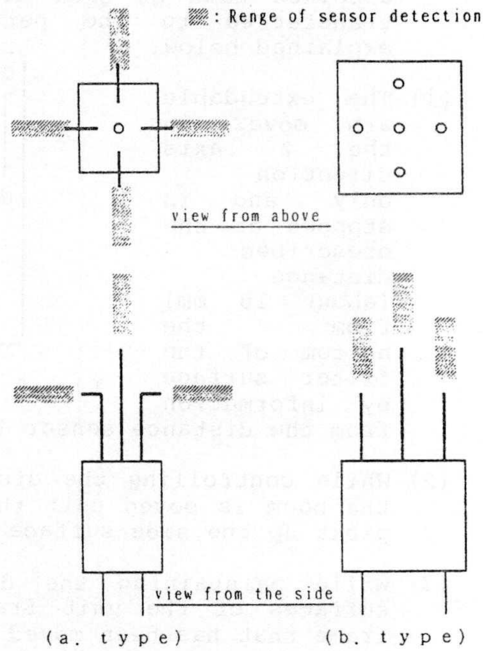


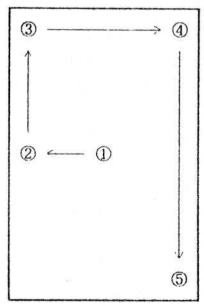
fig. 5 Detection sensor

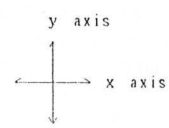
The "b" type sensor unit permits the tracing of the boundry line between the filter frame and the filter surface with permits the detection of the filter frame position through response by both sensors at the same time when the central sensor and one of the distance sensors straddles the filter frame, with, after unifying the detection direction of the sensor, making smaller the level difference of the distance detection area between the central and peripheral sensors compare with it between the filter surface and frame. Since the level difference between the filter frame and surface is not adequate (about 10 mm) as shown in the "b" type filter in Fig. 2 and, as mentioned above, the detection of the measured surface of the filter frame is difficult.
The above detection operations have been patterned and programmed, but since when the measurement arm or the sensor unit come into contact with filter, scratching may occur on the filter surface, so the data from each distance sensor is scanned by the controller within 1 ms and safe drive control is achieved.

3-3 Filter Position Detection Sequence

Fig. 6, 7 shows a depiction on the filter surface of the filter position detection sequence for both methods.

In Fig. 6, since the "a" type sensor unit is used, the movement of step motors at X, Y, and Z will pass through the controller as absolute data at each detection step from (1) to (5) and will be transferred to the personal computer. Steps (1) to (5) are explained below.





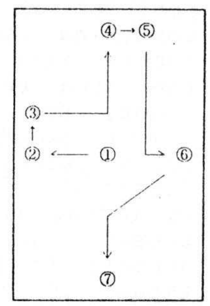


fig. 6 Four corner detection route   fig. 7 Four side detection route

(1) The extendable arm moves in the Z axis direction only and is stopped at the prescribed distance (about 10 mm) from the bottom of the filter surface by information from the distance sensor in the Z axis direction.

(2) While controlling the distance from the filter surface to be fixed, the boom is moved unit the distance sensor for the X axis direction picks up the side surface of the unit frame.

(3) While maintaining the distance between the filter and the side surfaces of the unit frame, one of the four corners of the unit frame that has been moved in the direction of the Y axis is detected.

(4)-(5) The positions of the other two conrners are detected by moving the side surface of the installation unit frame in the same manuever as in (3).
Three corners are detected using the above manuevers and the relative positional relationship between the leak check robot and the filter surface can be verified by calculating the X, Y and Z coordinates of the other corner since the measurement object is square or rectangular.
In Fig. 7, the position detecting sequence using the "b" type sensor unit is shown. Since in this type of detection object filter, the metal fitting protrudes outside the periphery of the filter frame in order to stop it , in the operations for detection of the outside periphery and verification of the four corner positions as shown in Fig. 6, control software has expanded greatly and since this causes an obstacle to reliability during driving, drive steps (1) to (7) shown in Fig. 7 have been established.

(1)-(2) One side of the filter frame will be taken in the same movement sequence as the "a" type sensor unit.

(3) While maintaining the conditions under which the position of the filter frame was picked up, a part of the area of the filter frame will be traced by moving measurement arm in the direction of the "Y" axis.

(4)-(5) One side of the other filter frame is picked up by moving in the direction where lines (1) (2) cross at right angles (using the same operation as in (2)) and the filter frame is traced using the same operation as in (3).

(6)-(7) (1) becomes the starting point for the drive method in operations and, measurement arm is moved to a perpendicularly crossing direction of lines (2) (6) and (4) (7), and positions (6) (7) of the other two sides of the filter frame are detected.
The absolute of the X, Y and Z axis for each point are obtained by the above operation. Since the filter frames of the measured filters are square and rectangular, the straight line that passes lines (2) (3) and (6) is parallel and the straight line that passes (7) and (4) (5) will also become parallel therefore, a linear expression where the four straight lines are shown will be formed. So, the detection attern has been made enable verification of the relative positional relationship between the four corners of the filter frame and the leak check robot by calculation of the X, Y, and Z coordinates that are the intersecion of each of the two straight lines, as in the detection method on the preceding page.

3-4 Sequence of Measurement

Since we talked about the automatic filter position detection method or the system outline in the description given on the preceding pages, we will explain the sequence of measurement operations.
In the computer, the measurement route is calculated from data sent from the controller. Since the measured drive data is calcuated according to such conditions as the measurement speed, distance from the filter surface and measurement pitch, the sequence of operations is based on the principle that the verification of conditions pertaining the filter has been completed. These are carried out as follows:
1) The original setting of the measurement boom is done by pushing the reset button of the controller.
2) The leak check robot is set at the bottom of the measurement object filter.
3) After completing the movement, the measurement operation begins by pushing the start button of the personal computer. (thereafter, automatic measurement)
4) When measurement is completed, it is moved to the next measurement site.
Measurement work is continued by repeating the above operations. Examples of the ooutput measurement results are shown in Fig. 8.

Table. 1 Specifications

Item	Details
Weight	approx. 60kg
Measuring range	Min. 1800～Max. 3400 (mm)
Resolution of the stepping motor	X. Y axis= 0.1 mm/step Z axis= 0.089 mm/step
Personal computer used	Fujitsu FM16－π
Controller CPU	Z－80
Reflecting fiber sensor	Detection renge = 25mm

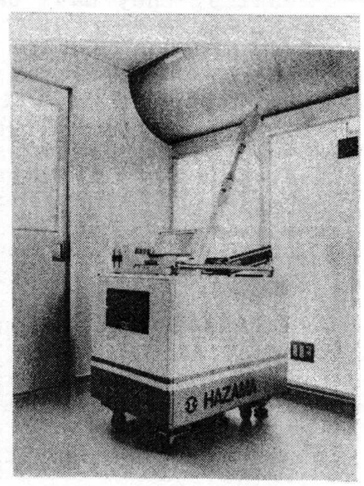


Photo No.1 Leax check robo

File No= 2 Registration No= AS002 Measured speed= 60
Judged numeric value of the measured results= 100
Particle diameter class of measured value= 0.3 um

(1)	2	(2)	0	(3)	1	(4)	0	(5)	0	(6)	1	(7)	0	(8)	1

File No= 7 Registration No= RT013 Measured speed= 100
Judged numeric value of the measured results= 300
Particle diameter class of measured value= 0.3 um

(1)	0	(2)	0	(3)	0	(4)	0	(5)	0	(6)	0	(7)	0	(8)	0
(9)	0	(10)	0	(11)	0	(12)	0	(13)	0	(14)	0	(15)	0	(16)	0
(17)	0	(18)	0	(19)	0	(20)	0								

fig. 8 Measured results

6. Conclusion

When the robot moves between operation sites, the robot is set at the starting point, all drive patterns are computationally processed and control methods such as the use of markings to verify the movement route, are generally used. In the case of computational processing, there are problems such as the occurance of reckless drive errors due to missing input data and there are basic set conditions prior to use such as the assurance of a run path. So when compared with the usage environment in the construction industry, these problems are becoming a source of obstruction to the promotion of robot usage.

Such engineering as positional detection or positional correction detection in relation to work objects through such things as pattern recognition using such devices as CCD (Charge Coupled Device) cameras are also being used, but instead of exhibiting substantial results, they have been linked with higher robot production costs.

Even though future computer technology will advance and moving robots which drive while automatically distinguishing work objects will appear, it will be a long time unit costs drop enough for their widespread use. Thus, when we consider robotization of construction work where complex work patterns are mixed, the recognition of behaviour patterns will be done by humans and specialized knowledge will be controlled by computers with human assistance. It is though that the introduction of a man-machine robot that combines human decisions are computer processing may accelerate the robotization of the construction industry.

In this case, design and development have been carried out based on these guidelines. The completion of a structure for automatic detection that was impossible up to now by pursuing control, simplicity and light weight, we feel the man-machine type robot will be adopted not only at eh on-line operating environment, but also at the off-line operating enviornment, such as construction industry fields.

Finally, our company also will continue to increase its store of know-how in the future to promote the use of robots in the construction industry.