

DEVELOPMENT OF A FULLY AUTOMATIC
CLEAN ROOM MEASURING SYSTEM

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ABSTRACT

The more highly the performance of clean rooms are required, the more frequently and closely we must measure and analyze the environment of them, not only as built facility but also as operating facility. Fully automatic clean room measuring system "CLEAN-WATCHER" has been developed in order to automatically measure and analyze the particle concentration, temperature, humidity, wind velocity distribution and to carry out scan test of filters attached on ceiling, at any position in down flow clean rooms without attendance of operator. This paper describes the outline of this system.

1 Introduction

With the increasing requirements for the performance of clean rooms, filter scan tests and other measuring and analyses for particle concentration, temperature, humidity, wind velocity distribution, and other environment conditions are required during normal "Operating Facility" in addition to testing at the time of "As Built Facility", in order to maintain the performance.

As the robot "CLEAN-WATCHER (in the following called CW)" has been developed for automatic measuring and analyses of these environment conditions of the experimental clean room in our laboratory, it shall be outlined in the following.

2 Outline of the CLEAN-WATCHER

Table 1 shows a classification of the robots used by the various construction companies for clean room measuring and analysis. A large number of the robots used until now is of the traverse type. The traverse type is superior to the automated-guided-vehicle (AGV) type in regard to the positioning accuracy, but rails or a special frame for running are required, and the freedom of the experimental clean room in our laboratory is impaired. As the AGV type requires no fixed rails etc., the system can be developed for use not only in the experimental clean room but also for grasping of the performance of the "As Built" or "Operating" facilities in producing factories.

Thus the basic policy of using a AGV type was decided, but various problem points are assumed for the already developed AGV type clean room measuring robots¹⁾. Accordingly, the following development targets were set.

- (1) Free travel shall be possible on grating, and the positioning accuracy shall be within ± 5 mm for the vehicle.
- (2) Sensor movement shall be possible to all points of the experimental clean room in our laboratory, and there shall be no measuring loss locations (150 mm to 3000mm above the floor).
- (3) A language as simple as BASIC shall be used, and unmanned mobile measuring shall be possible with batch processing.
- (4) Generation and editing of teaching data shall be possible outside of the clean room.
- (5) Mobile measuring with loading of various measuring instruments with an RS232C communications interface shall be possible (particle concentration, temperature, humidity, wind speed, etc.).
- (6) The size shall be so that transporting to locations outside of the clean room laboratory is possible through doors of normal size, and the weight shall be light.
- (7) No particles shall be emitted from the robot body to clean rooms.
- (8) The robot shall be equipped with sufficient safety devices.
- (9) Use for applications other than measuring (repeated testing etc.) also shall be possible.

3 System Composition and Functions

The system composition is shown in Fig.1, the system control mechanism is shown in Fig.2, and the main specifications are shown in table 2.

The functions are explained in the following.

(1) Vehicle

The measuring instruments are loaded onto the rear of the vehicle for movement. The vehicle can travel freely in X and Y direction. The wheels have a large diameter and a large width, and for change of the travelling direction, outriggers installed at the four corners of the vehicle are used to raise the vehicle for turning of the entire drive mechanism.

In this way, the movement direction can be changed without changing the orientation of the vehicle.

(2) Manipulator

The manipulator is a vertical type with 6 joints, and complicated movements

are possible. The manipulator movement is assumed to permit handling of semiconductor wafers, and smooth movement can be realized.

(3) Sensor Holder

The sensor holder is located at the tip of the pall installed at the tip of the manipulator, and the sensor is fixed with rubber bands. As the sensor holder uses a pendulum mechanism, the sensor always maintains the same direction even when it is moved to any point from 150 mm to 3000 mm above the floor.

(4) Measuring Instrument Loading Part

The instruments are fixed with a belt inside an acryl case. For a measuring instrument AC 100 V, and an RS232C connector are provided.

Measuring is possible for the 4 types of particle concentration, temperature, humidity, and wind velocity, and table 3 shows an outline of presently mounted measuring instruments.

(5) Camera

As wheels are used for travelling, with positioning by means of an encoder coupled with the motor, it is not possible to avoid position errors caused by slip between the wheels and the floor. In order to compensate for this error, a CCD camera is installed at the tip of the manipulator, the video signal from the camera is converted to a binary black-and-white signal, divided into 512 X 512 picture elements, and taken into a frame memory. A bar code pattern is recognized from this picture information.

(6) Bar Code

The bar code is a pattern consisting of black and white bits, and it is applied to the floor. The picture is recognized by the CCD camera, the side position of the truck from the path X, the distance Y between the bar code and the vehicle center, and angle θ between the vehicle center line and the path are read, and the deviation is compensated automatically.

The vehicle position is compensated by bar code application at the measuring coordinate origin or an intermediate point, and the travelling accuracy is improved.

(7) Operation Part

This is formed by a personal computer. The entire CW operation can be executed from outside the clean room.

(8) Safety Measures and Devices

a) Ultrasonic Sensor

One sensor each is installed at the center of each side of the vehicle to decelerate the vehicle when a wall, a human, or any other object is detected.

b) Bumper Sensor

This sensor is arranged on the lower circumference of the vehicle and stops

the movement of the robot on contact with an object.

c) Touch Sensor

This is installed at the pall tip in approximately the same position as the sensor holder, and the robot movement is stopped when this sensor comes into contact with an object.

d) Other Safety Measures

An emergency stop switch, a wire break detector, a motor overheat detector, and other self-diagnosis functions are provided.

(9) Cable Part

Wireless transmission of the CW operation and measuring date has been investigated, but as the power supply capacity of the built-in fan of the particle counter for measuring of the particle concentration is large, a wire method was adapted for the CW developed this time.

There are two cables, one for power supply and one for signals, and the cables are paid out or reeled in automatically according to the vehicle movement.

(10) Countermeasures against Particle Emission

Possible CW particle sources are motors, transmission system, bearing, wheels, cables, lubrication oil, cooling fan, etc. In order to prevent spreading of particles from these particle sources, the bearings are provided with magnetic fluid seals, a suction fan is installed at the bottom part of the manipulator to obtain a negative pressure for the inside, and the particles are discharged from the vehicle bottom and the rear bottom (refer to Fig.3).

In order to confirm the effect of these countermeasures, measuring has been executed in the experimental clean room in our laboratory²⁾.

No particles of $0.1\mu\text{m}$ or more were detected directly below the manipulator joints and in the direct vicinity of the vehicle, except for the cable outlet.

The total discharged particles through the vehicle bottom and the cable outlet by the effect of a suction fan installed were about 300,000 particles per minute with a size of $0.1\mu\text{m}$ or more and 20,000 to 40,000 particles with a size of $0.3\mu\text{m}$ or more, which is 1/100 or less of the particles emitted from a walking human clothed in clean room garments³⁾.

4 Measuring by Means of the CLEAN-WATCHER

Measuring by means of CW is executed in the following sequence.

- (1) Input of measuring items, mode, teaching date file name, etc. from the operation part (personal computer).
- (2) Origin return for manipulator and vehicle.
- (3) Reading of the bar code on the floor with the CCD camera at the manipulator

tip and correction of the vehicle position.

- (4) Movement of the vehicle, measuring sensor positioning with the manipulator at the measuring points.
- (5) Measuring with the measuring instruments.
- (6) Transmission of position data and measuring data to the personal computer.
- (7) Display of measuring data and measuring points on the CRT and saving of the data onto a floppy disk.
- (8) Repetition of the steps (4) to (7).

After completion of measuring, the data are analyzed, and counter indication of the distributions is possible.

For execution of scan test for HEPA filters or other filters installed in the ceiling, the vehicle is moved to under the filter, and then linear interpolation operation is executed for the manipulator.

For execution of these series of operations, the position data must be taught in advance, but when teaching has been done once, the same teaching data can be used repeatedly even for measuring of other items, so that wide improvements can be obtained in regard to work reduction for the measuring and data reliability.

5 Conclusion

The fully automatic clean room measuring system CLEAN-WATCHER presently operating in the experimental clean room in our laboratory has been outlined.

The CLEAN-WATCHER developed this time basically has the functions for transport of semiconductor wafers, and it is believed that investigation of the influence of particles and vibrations generated by the robot body will contribute widely to automation and robot introduction for the semiconductor industry. Also, the successful development of a system permitting measuring at several points up to several hundred points without entry into the clean room is considered as contributing to the future development towards unmanned environment control systems for clean rooms.

REFERENCES

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- 2) S.Kosaka and A.Ohsakaya, " In Regard to a Clean Room Automatic Measuring Robot, Part2. Particle Generation Characteristics of the Robot ", Summaries of Technical papers of Annual Meeting, Architectural Institute of Japan,pp1181-1182, 1987
- 3) Guidance for Operation of Clean Room, Japan Air Cleaning Association, 1984

Table 1 Classification of the Robots Used for Clean Room Measuring and Analysis

Classification	Measured Item	
Traverse Type	Floor Rail	<ul style="list-style-type: none"> •Particle (Concentration, Filter Scan Test) •Temperature •Humidity •Air Verocity
	Ceiling Frame	•Particle (Filter Scan Test)
AGV Type	AGV only	•Particle (Concentration)
	AGV & XY Table	•Particle (Filter Scan Test)
	AGV & Manipulator	•Particle (Concentration, Filter Scan Test)

Table 2 Specifications of CLEAN-WATCHER

Item	Specifications	
Mechanism	•Dimension	<ul style="list-style-type: none"> •Vehicle : 1060mm^L*710mm^W*800mm^H •Manipulator : First Arm 400mm, Second Arm 400mm
	•Weight	<ul style="list-style-type: none"> •Vehicle and Manipulator : 220kg •Power Supplying Box : 30 kg
	•Camera	<ul style="list-style-type: none"> •Camera : CCD Camera •Lense : f=16mm
	•Bar Code	•100mm*100mm*2mm ^t , 5bit
	•Service Outlet	•AC 100V, 3A
	•Power Supply	•Capacity 2KVA
	Function	•Positioning Accuracy
•Speed		<ul style="list-style-type: none"> •Vehicle : 0~20m/min •Manipulator : 0~200mm/s
•Carrying Capacity		<ul style="list-style-type: none"> •Dimension : 440mm^L*470mm^W*290mm^H •Weight : 30kg
•Guidance System		•Bar Code and Vision System
•Sampling Head		•Controlled by Pendulum
•Communication		<ul style="list-style-type: none"> •Personal Computer : RS232C •Mesuring Instrument : RS232C
•Advancing Direction		•All Directions
•Floor Type		•Flat Floor or Grating Floor
•Cable Control		<ul style="list-style-type: none"> •Drum Revolutions : Same as Wheel Revolutions •Maximum Length : 9.5m •Over Tension : Tension Sensor

Table 3 Measuring Instruments Mounted on CLEAN-WATCHER

Measured Item	Type	Specifications
Particle	RION KC-03	Particle Size Range : 0.3~5.0 μm Sample Flow : 3 l/min (0.1ft ³ /min)
Temperature	RISYO DMT-610	Sensor : Crystal Probe Range : -50~15°C Accuracy : $\pm 0.1^\circ\text{C}$
Humidity	VAISALA HMI-32	Range : 0~100%RH Accuracy : $\pm 2\%$
Air Verocity	RION AM-10	Sensor : Transistor Probe Range : 0.05~25m/s Accuracy : 0.05m/s
Electric Current, Voltage	ETO THERMODAC32	18 Channel Analog Data 10 Channel Pulse Data 4 Channel Digital Data

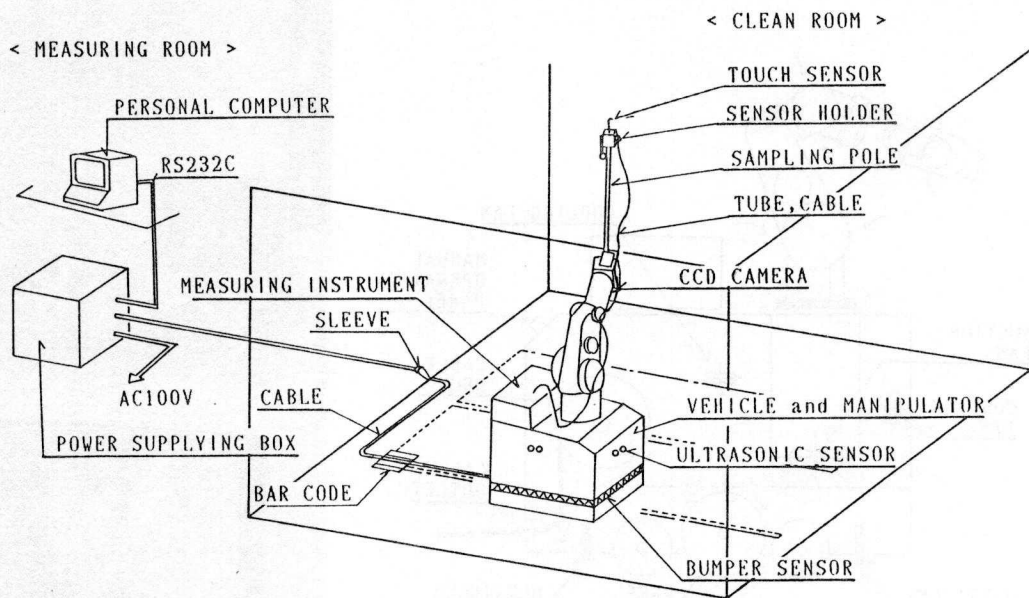


Fig.1 System Composition of CLEAN-WATCHER

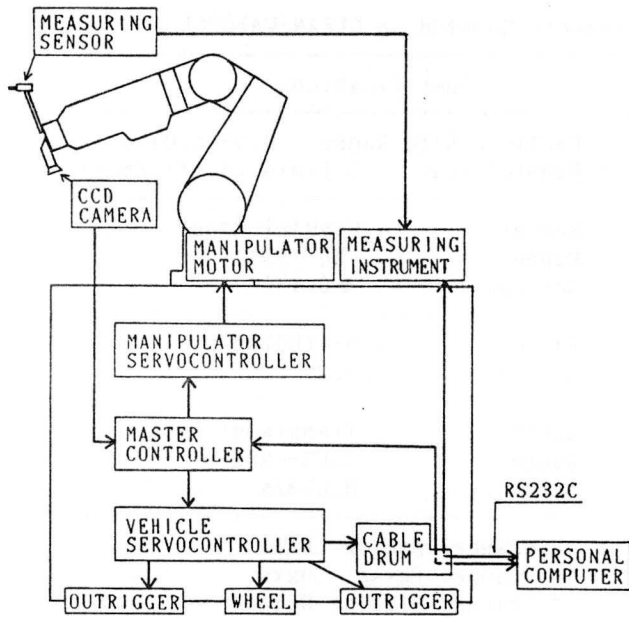


Fig.2 System Control Mechanism

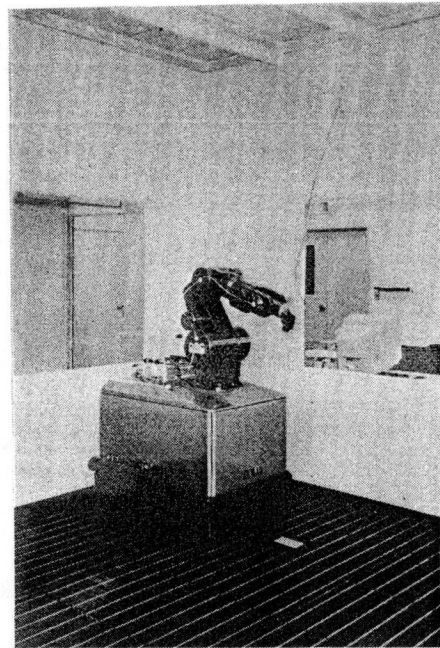


Photo.1 General View

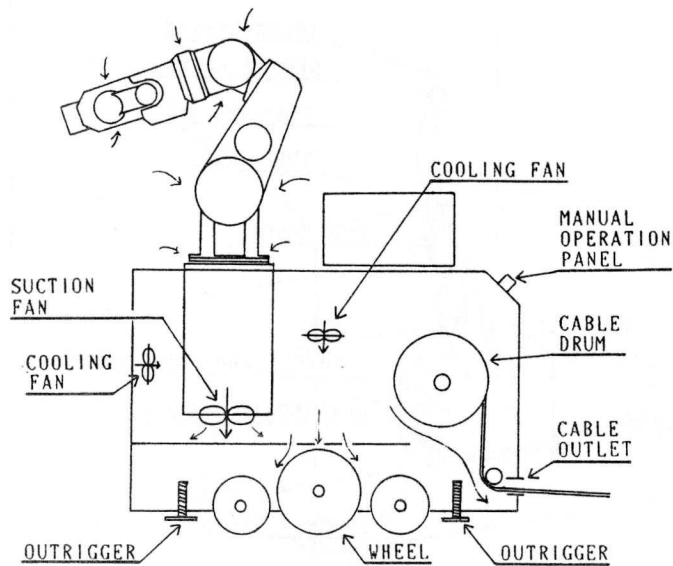


Fig.3 Countermeasures against Particle Emission

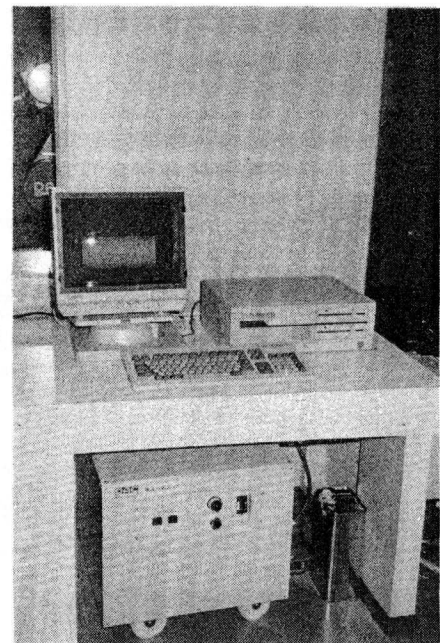


Photo.2 Operation Part