Ultra-Clean Technology for High Density Magnetic Hard Disks

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1. Introduction

With the dramatic proliferation and higher performance of personal computers, higher quality is increasingly demanded of magnetic hard disks (hereinafter referred to as the disk) mounted on hard disk drives.

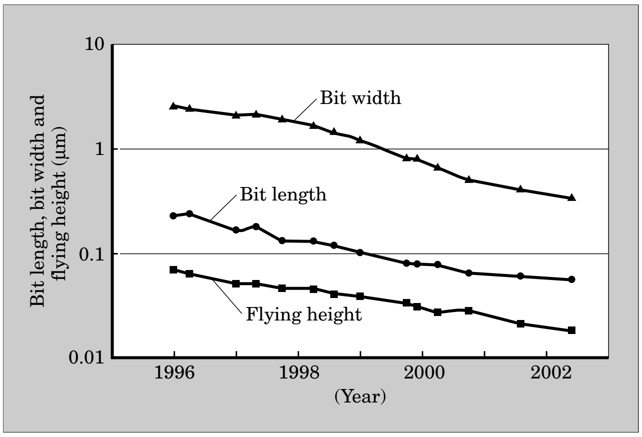
One of the factors affecting the trend mentioned above is the widespread use of hermetically sealed drives without any openings for air intake. As the use of drives become more widespread, applications in adverse environments coupled with mobile usage will disrupt the humidity and temperature balance in the drives, leading to dew condensation on the surface of the disks. Adsorbed water due to dew condensation reacts with ionic contaminants, and can corrode and dissolve thin film magnetic materials and lubricant.

Another factor is the challenge of higher recording density. In recent years, the size of the recording bit of disk platters where digital data is recorded has become extremely small, 0.8 μm × 0.07 μm in currently mass-produced types. If there are defects of approximately the same size as mentioned above, some reproduced data will be missing. On the other hand, since the gap between a disk and a recording head (flying height of the head) is small (0.03 μm), dust on the surface of the disk will scratch the surfaces of the recording head and disk, and in the worst case, recorded data will be lost. The size of the recording bit and flying height have been exponentially decreasing as shown in Fig. 1, and this trend will continue in the future.

With higher recording density, contamination of disk surfaces during processing must be kept to a minimum, necessitating a total control of environment, materials and equipment in a clean room, (refer to Table 1).

This paper presents an overview of contamination control in a clean room and contamination prevention of disk surfaces and countermeasures against electrostatic hazards.

Fig.1 Transition of bit size and head flying height versus year



2. Contamination Control in a Clean Room

Contaminants in a clean room are divided into two major categories: particle contaminants, and gaseous chemical contaminants that cannot be removed with a dust removal filter. The recent development of high efficiency filters such as HEPA (high efficiency particulate air-filter) and ULPA (ultra low penetration air-filter) has made it possible to control dust contaminants. Thus, the control of gaseous chemical contaminants has become commonplace within a clean room.

Chemical contaminants are acids, alkalis and organic gases, that come from equipment, workers, construction materials, cassette materials and outside air. The contaminants are selectively adsorbed by the surfaces of a disk and recording head, exerting an adverse effect on product quality.

Chemical contaminant control can be broadly classified into three methods: “do not bring in,” “do not generate,” and “removal.” The “do not bring in” and “do not generate” methods use construction materials and cassette materials in the clean room having a low amount of outgassing. The “removal” method is implemented by installing a chemical filter and an air washer. Figure 2 shows a schematic diagram of an air conditioning system in a clean room.

2.1 Chemical contaminant control in a clean room

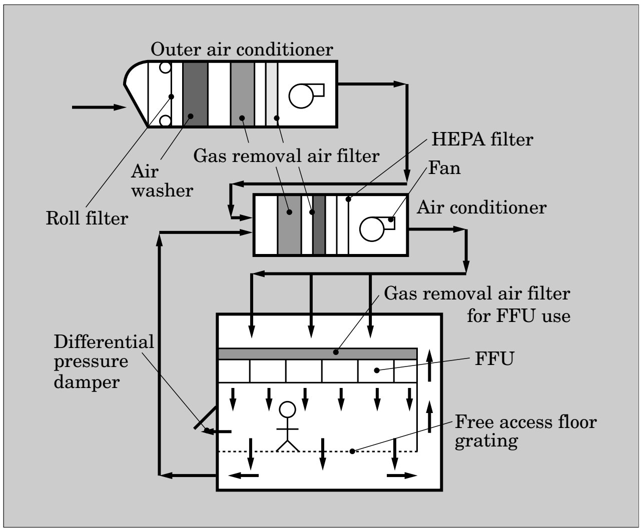
2.1.1 Contamination control due to air flow control

If dust contaminants are adsorbed by products in a clean room, they exert an adverse effect on product

Table 1 Summary of cleaning items and their evaluation

Item		Object	Evaluation	Measurement frequency
Clean room environment	Air flow control	Air flow	Air flow visualization system	Whenever necessary
	Monitoring	Dust in the air	Automatic particle counter	Continuously
		Temperature, humidity, room atmospheric pressure	Automatic monitor	
		Ion components in the air	Impinger collection → IC	Every week
			Witness disk → IC	
		Organic components in the air	Adsorption by the disk when left standing → FTIR	
			Adsorption by activated carbon → GC-MS	Whenever necessary
	Selection of construction materials	Ion components	Ultra pure water extraction → IC	When constructing or reconstructing the clean room
		Organic components	Concentrated collection → GS-MS	
Filtration	Filter	Ion components	Impinger collection → IC	Every month
		Organic components	Adsorption by activated carbon → GC-MS	Whenever necessary
	Air washer	Water	Electrical conductivity sensor	Continuously
		Ion component in the water	Impinger collection → IC	Every month
Contamination check of finished products		Ion components	Ultra pure water extraction → IC	Every week
		Corrosion	Ultra pure water extraction → ICP	
		Organic components	Ultra pure water extraction → FTIR	
Materials, utility	Lubricant, solvent	Ion components	IC	Every week
		Organic components	FTIR	
	Ultra pure water	Particles, ion components	Particle counter, IC	Continuously
	Cassette, bag	Ion components	Ultra pure water extraction → IC	Every week
		Organic components	Ultra pure water extraction → FTIR	
			Concentrated collection → GS-MS	When selected
		Particles	Particle counter	Every week

Fig.2 Air conditioning system in a clean room



quality. Although a dust removal filter is generally used for this purpose, that by itself is insufficient. Air flow control is necessary to exhaust dust contaminants generated in the clean room out of a production process without contaminating products.

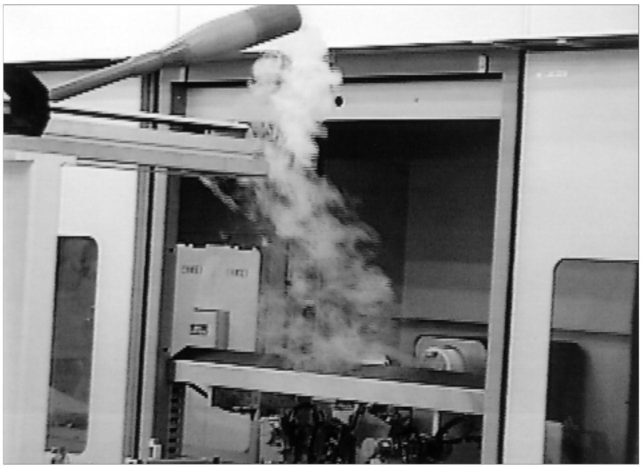
Air flow control requires that parameters such as the positions of air inlet and outlet openings, air flow rate and the layout of equipment in the room be adjusted to prevent turbulence, including the consideration of a push-pull construction for air inlet and outlet openings. At present, design of air flow control is mainly based on a simulation conducted at the time of construction. Special attention must be paid to the fact that even if there was no trouble in air flow control at the beginning, turbulence caused by changes to the layout of line equipment or other factors could contaminate products as time goes by.

Therefore, after layout, air flow in the clean room must regularly be monitored by an air flow visualization system. Points that are detected as causing turbulence are altered. Figure 3 shows the verification of air flow with an air flow visualization system.

2.1.2 Monitoring of dust contaminants

Maintaining cleanliness in a clean room requires regular monitoring based on control criteria. A centralized supervisory system is constructed to simultaneously monitor in real-time the dust suspended in the air, dust suspended in liquids, temperature and humidity in the clean room so that countermeasures can be implemented against sudden abnormalities.

Fig.3 Verification of air flow with a visualization system



2.2 Countermeasures against chemical contaminants in a clean room

2.2.1 Contamination control due to selection of construction materials in a clean room

Organic gases from chemical contaminants are mainly emitted by construction materials used for the clean room's interior and cassette materials. To cope with this, construction and cassette materials that only emit a small amount of outgas were selected to construct a clean room having few organic gases.

(1) Selection of construction materials

Construction materials used in a clean room include paint, adhesive, wall and floor materials, resin mold, tape and other materials.

First, materials emitting low aggregate amounts of organic gases and specific components with low amounts of outgases were selected from among potential construction materials using a gas chromatograph-mass spectrometer (GC-MS). Specific components include siloxane and dioctyl phthalate (DOP), possibly harmful to the quality of products.

Secondly, construction materials with ionic components below reference values were selected by analyzing them with an ion chromatograph (IC). Figure 4 shows sealant analysis results as an example of the analysis of construction materials. It was determined from the results that sealant A emitted a small amount of gases and their ion components were below reference values. On the other hand, sealant B emitted a rather large amount of gases, and gases such as DOP were identified, and the material was judged as improper.

(2) Confirmation of effect of selection of construction materials

To confirm the effect of the selection, organic gas concentration was verified for clean rooms A (CR-A) and B (CR-B), which were constructed in different times. CR-B contains the latest high-tech equipment and was constructed 18 months after the installation of CR-A. CR-B was provided with construction materials selected for their low outgassing.

Fig.4 Sealant analysis results with a GC-MS

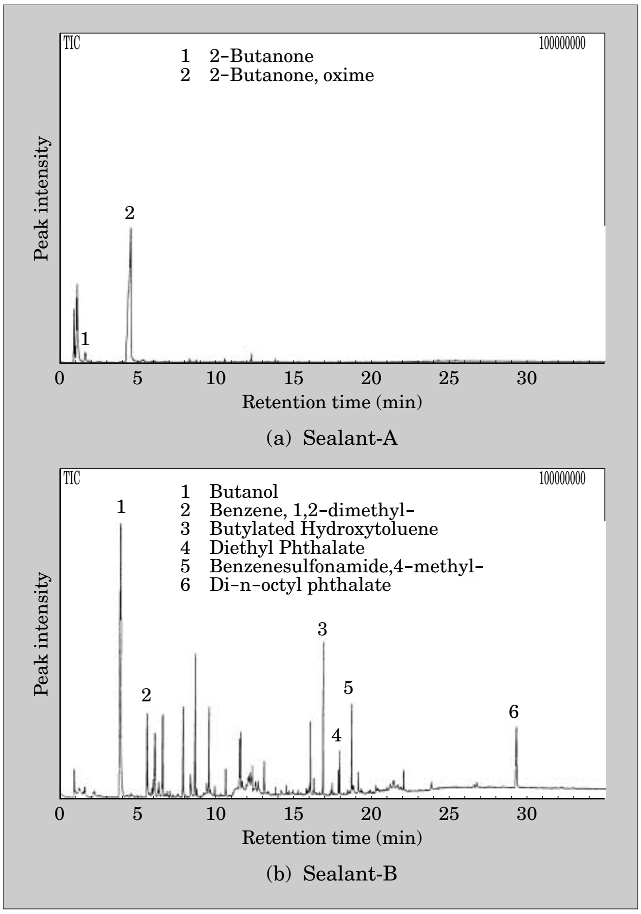


Fig.5 Transition of organic gas concentration

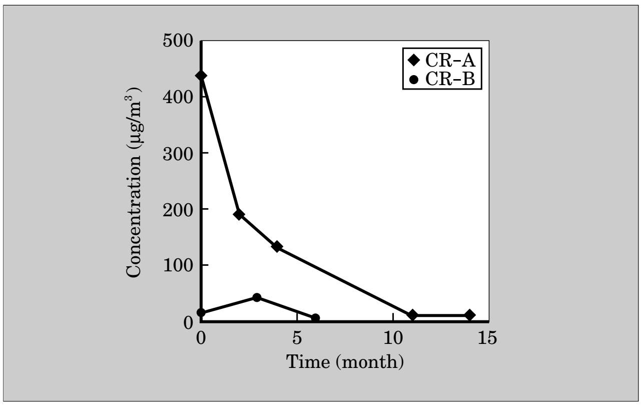


Figure 5 shows the transition of the organic gas concentration of CR-A and CR-B. It was confirmed that CR-B had much lower organic gas concentration immediately after and since its construction, compared with CR-A. This demonstrated the effect and importance of material selection.

2.2.2 Contamination control due to installation of a chemical filter and other devices

Chemical contaminants enter a clean room from equipment and workers in the clean room and from outside air, in addition to construction and cassette

Fig.6 Witness of the disk

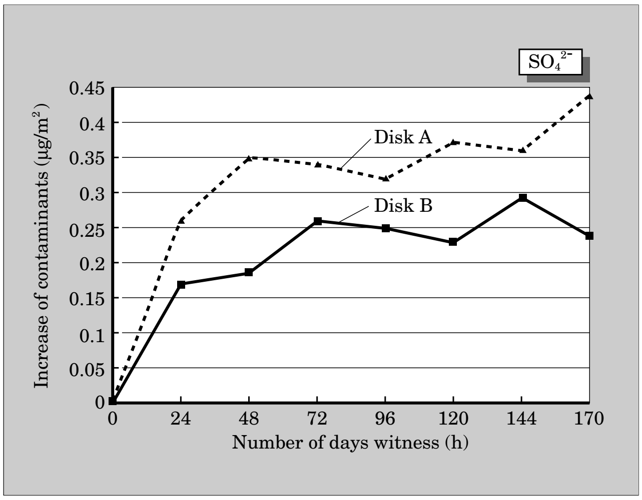
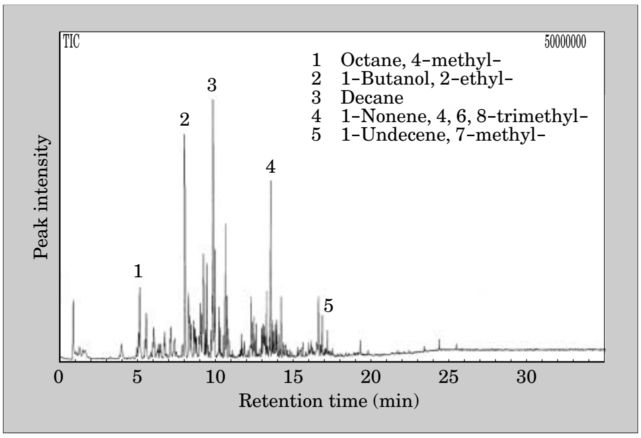


Fig.7 Analysis of a PP cassette cover before implementing measures against outgassing



materials. Countermeasures only against construction and cassette materials are insufficient. Thus, a chemical filter and an air washer are used to reduce or remove harmful gases.

(1) Contamination control with a chemical filter

Various types of chemical filters have been developed and an appropriate filter for the gas components should be used. At present, an ion exchange filter is used for alkaline gases, a chemical adsorption filter for acidic gases, and an activated carbon filter for organic gases. When required, filters are installed in the air circulation system and in an outer air conditioner. The number of filters installed varies with gas concentration settings.

(2) Contamination control with an air washer

Chemical contaminants also enter a clean room from outside air entering a circulating system. The outer air contains SOx, NOx, etc., and their concentration varies with meteorological conditions and the direction of a wind, affecting gas concentration in the air circulation of the clean room. An air washer is used together with a filter to remove the gases, because providing the outer air conditioner with only a filter is neither sufficient not cost-effective.

An air washer is a system intended to remove chemical contaminants in the outer air by absorbing them with water. This system passes the air through a spray of pure water before taking the air into the clean room circulation system.

Special care must be taken because the contaminant removal rate decreases when the contaminant concentration in the water increases. Pure water used for the air washer is automatically controlled with an electrical conductivity sensor to maintain a specified removal rate.

2.2.3 Monitoring of chemical contaminants

Chemical contaminants are monitored based on established methods of sample collection and analysis. At present SOx, NOx and ammonium are automatically monitored with a sulfur oxide meter and others. Detection limits can be circumvented and a large amount of information can be processed by combining sample collection with analysis. Sample collection includes collection with an impinger and activated-carbon tube. Analysis is conducted with IC and GC-MS. Automatic monitoring with IC is being considered by some manufacturers.

3. Contamination Control of Disk Surfaces

Contamination control of disk surfaces requires a comprehensive control of environment, processes, packing materials and workpiece materials to be surface-processed. As mentioned before, with the increase of packing density, stricter contamination control is required. The present challenge is how to achieve an effective contamination control. Contamination control currently in use for disk surfaces is presented below.

3.1 Control of residence time in the process

In the processes following sputtering, control of the environment during the lubricant coating process and residence time during disk processing is important for contamination control of disk surfaces. Carbon layers closest to the disk surface are, in general, sensitive to contamination until they are coated with lubricant. As shown in Fig. 6, the amount of contaminants adsorbed by the disk increases with residence time.

Based on the findings, strict control of residence time during processing is conducted to minimize the adsorption of contaminants. Time control is conducted using a production control system and the disk quality is verified through analysis using IC of pure water extracted from the disk.

3.2 Control of disk contamination due to cassettes and packing

Since disk loaded on cassettes for a long time is subject to outgas from the cassettes, examination of

Fig.8 Analysis of a PP cassette cover after having implemented measures against outgassing

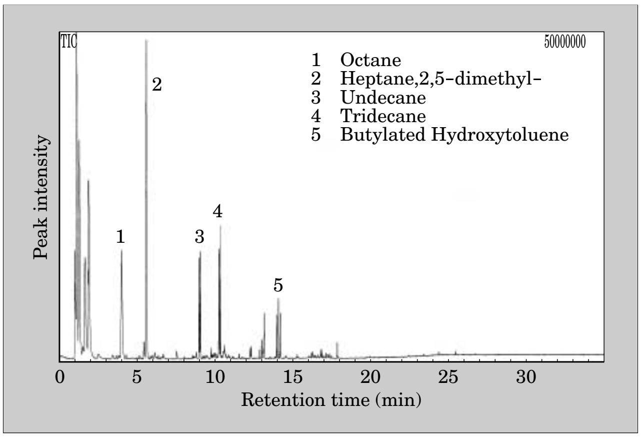
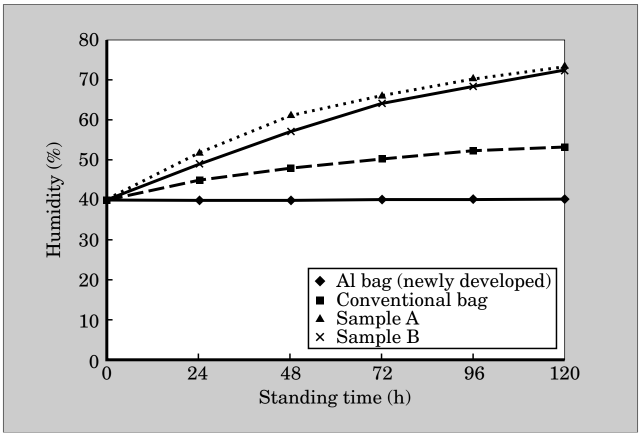


Fig.9 Water vapor permeability characteristics versus time



resins used for cassettes and confirmation of cleaning quality are very important.

Today, the dominant cassettes to be antistatic finished consist of a body made of polycarbonate (PC) and upper and lower covers of polypropylene (PP). Both PC and PP must fully be checked for dust generation and outgassing. Quantitative control must regularly be made to check if the cassettes contain a large quantity of plasticizer and sizing materials, contaminants easily adsorbed by the disk surface. In particular, special attention must be paid to specific polymeric compounds such as BHP, DBP, DEP and siloxane, contaminants requiring extra caution, because they were claimed to be responsible for some accidents in the past. Analysis is regularly performed to check the quality of the disk by an FTIR(Fourier transform infrared spectrophotometer), extracting solvent from the disk, and by a high sensitivity concentration method based on GC-MS purges and traps.

3.2.1 Improvement in the quality of cassette materials

Outgassing from cassette materials can be substantially reduced by joint efforts with the cassette manufacturer, resulting in simplification of the cassette cleaning process.

Figures 7 and 8 show an example of improvement in the quality of cassette materials. Due to this improvement, the gas cure process during cleaning can be omitted.

3.2.2 Improvement in the quality of packing materials

Contamination control against packing materials and enhancement of environmental barrier characteristics are also important topics in the prevention of disk surface contamination.

(1) Outgassing

Materials having a low amount of outgassing were examined and selected with a GC-MS as is the case with cassettes.

(2) Environmental barrier characteristics (water vapor permeability)

Figure 9 shows an example of the improvement from implementing measures against humidity during transportation. Fuji Electric, in collaboration with a packing material manufacturer, has developed and put to practical use a new four-layer bag using aluminum and new-generation packing materials. This bag is provided with measures against static electricity and features enhanced strength.

3.3 Monitoring of contaminants (workpiece materials, clean room, process, finished goods)

Surface contamination of the disk and its environment are continuously monitored with regard to the items listed in Table 1. These items are regularly measured by week, by month and by lot. A database is created from these results and necessary data is fed back to production processes for the purpose of contamination control and improving product quality.

In the future, Fuji Electric will clarify the relationship between disk reliability evaluation items and contamination control items and will reconstruct an efficient quality assurance system to meet the needs of next-generation disk.

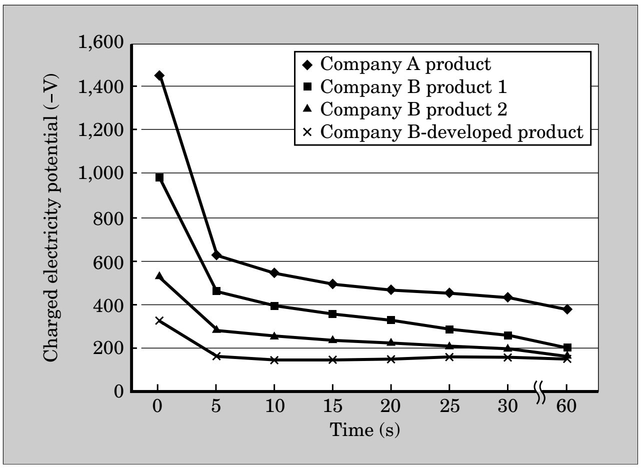
4. Static Electricity

Static electricity causes contamination due to dust deposition and electrostatic discharge failure in workpiece materials.

(1) Countermeasures against static electricity are the last to be implemented against contamination due to dust deposition. Charged electric potential must be 50V or less to prevent the deposition of dust particles of 0.5 μm or more in diameter. In a disk production process, grounding of the product transfer system and use of conductive materials for cassettes and humidity control are implemented as countermeasures against contamination due to dust deposition.

(2) As for the breakdown of workpiece materials, countermeasures against electrostatic discharge failure are implemented on the GMR (gaint magnetoresitive) head during testing. The counter-

Fig.10 Charged electricity potential characteristic of clean garments versus time



measures include ① grounding, ② use of conductive materials, ③ humidity control and ④ use of an ionizer.

① A testing machine and workbench for exchanging GMR(giant magneto-resistive) heads were grounded. The charged electric potential of a human body can be reduced from 1,500V to 3V or less by the use of a wristband.

② Use of conductive materials permitted the charged electric potential of substrates in the cassettes to be reduced from 2,310V to 5V or less, covers to be reduced from 2,200V to 3V or less and chairs from 7,910V to 5V or less.

③ Humidity is controlled and maintained at greater than 45%.

④ An ionizer with an AC special-type fan which can control the ion balance within a range of ±5V was selected and used for GMR head exchange on the workbench.

Fuji Electric has asked a manufacturer to develop clean garments equipped with countermeasures against static electricity. Changing the fibers in clean garments from hydrophobic to hydrophilic reduced the charged electric potential from 350-470V to 10V or less when wearing the garments on a conductive floor, and from 600-1,500V maximum to 300V when wearing them on an insulated material. These results are shown in Fig. 10, illustrating the advantage of changing fibers. Fuji Electric is also considering the development of gloves.

5. Conclusion

This paper has presented improvements to the clean room environment and management, and methods to verify the products. These procedures must continuously be improved as higher performance hard disks are required.

On the other hand, within several years revolutionary changes in the concepts for magnetic hard disks will possibly be needed, particularly when production processes are substantially changed due to the introduction of a perpendicular magnetic recording system and an optically assisted recording system, and alternative substrates are utilized to meet cost reduction goals. To satisfy these needs, the development and enhancement of clean technology will be required.