



JEITA Guideline  
for F-GHG Characterization and Management

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Prepared by  
Semiconductor Environment and Safety Committee

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(JEITA)

In case of a disagreement between the translation and the original Japanese version of the guideline or technical report, the original version will prevail.

[NOTICE]

This Guideline will be approved by the Semiconductor Environment and Safety Committee in October, 2011.

[Foreword]

Global warming is thought a serious problem with which the world is faced now.

We think that an understanding the amount of F-GHG emissions is important for JEITA members in order to tackle global warming. Suitable and efficient techniques to identify the amount of F-GHG emissions play successful roll.

According to the 2006 edition of the IPCC (Intergovernmental Panel on Climate Change) guideline, each default value for the DRE (Destruction or Removal Efficiency) of an abatement system can be utilized under the using conditions that the system performance is measured and achieved.

This document provides following guidance to plan the emissions reduction for a user of F-GHG.

For suitable characterization of F-GHG emissions from a manufacturing tool and an abatement system

- How to measure the F-GHG emissions
- How to determine the frequency of the measurement
- How to plan the emissions measurement
- How to manage the data

We at JEITA Semiconductor Environment and Safety Committee disclose this guideline for determining scope of F-GHG emissions characterization. In addition, we will continually update the guideline to meet engineering and management technologies improved hereafter. We hope this guideline is effectively and widely used.

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## **1 Purpose**

1.1 This guideline proposes the efficient measuring method of the amount of F-GHG emissions, and the management of characterization.

1.2 This guideline proposes the efficient measuring method of the utilization of F-GHG for manufacture tools and the DRE of F-GHG for abatement systems in Semiconductor and Liquid crystal industries.

1.3 This guideline proposes the management method of the timing, the frequency and the measurement procedures.

1.4 This guideline provides users with the technical know-how which can be used for the operation management of process tools and abatement systems.

## **2 Scope**

2.1 This guideline is applied to the characterization of the amount of emissions and the utilization of F-GHG of the manufacturing tools in Semiconductor and Liquid crystal industries

2.2 This guideline is applied to the characterization of the amount of emissions and the DRE of F-GHG of the abatement systems in Semiconductor and Liquid crystal industries

2.3 This guideline aims at the following seven kinds of greenhouse gas mainly used by the semiconductor industry among FCs (Fluorinated Compounds). We denote these gases as F-GHG.

(1) CF<sub>4</sub>, (2) C<sub>2</sub>F<sub>6</sub>, (3) C<sub>3</sub>F<sub>8</sub>, (4) c-C<sub>4</sub>F<sub>8</sub>, (5) CHF<sub>3</sub>, (6) SF<sub>6</sub>, (7) NF<sub>3</sub>

### 3 Limitations

- 3.1 This guideline does not obligate characterization of F-GHG emissions, the utilization and the DRE.
- 3.2 This guideline is not intended to restrict characterization method of F-GHG emissions, the utilization and the DRE.
- 3.3 This guideline is not intended to restrict data management of F-GHG emissions, the utilization and the DRE.
- 3.4 This guideline does not set targets about F-GHG emissions, the utilization, the DRE and the characterization frequency of F-GHG.
- 3.5 This guideline is not the one taking the place of the law and the restriction of the region of the user.

NOTICE: This guideline does not purport to address safety issues, if any, associated with its use. Users of this guideline establish appropriate safety and health practices and determine the applicability of regulatory or other limitations prior to use on their responsibility.

### 4 Referenced Standards and Documents

### 5 Terminology

	Abbreviation	Standard nomenclature
1	DRE	Destruction or Removal Efficiency
2	FCs	Fluorinated Compounds
3	F-GHG	Fluorinated GreenHouse Gas
4	FT-IR	Fourier Transform - InfraRed
5	IPCC	Intergovernmental Panel on Climate Change
6	ISMI	International SEMATECH Manufacturing Initiative
7	QMS	Quadrupole Mass Spectrometer
8	SEMI	Semiconductor Equipment and Materials International
9	SEMATECH	Semiconductor Manufacturing Technology Institute

### 6 Measurement Tool

The certificated tool should be used for the measurement.

The outline of FT-IR and QMS illustrated as a measurement tool in this guideline should be referred to "12.1 Outlines of measuring instruments" in "12 Related Information".

## 7 Characterization Method of F-GHG

The amount of each emission is defined as the production of the concentration, the flow rate and time.

$$V_i = C_i \times F_i \times T$$

$V_i$ : Gas volume for  $i^{\text{th}}$  gas

$T$ : Total time for measurement

$C_i$ : Concentration for  $i^{\text{th}}$  gas

$F_i$ : Gas flow rate for  $i^{\text{th}}$  gas

This chapter shows the characterization method.

- 1) Measure the F-GHG concentration.
- 2) Measure flow rate and time.
- 3) Calculate the amount of F-GHG including the by-product exhausted from the equipment and various devices.

By the calculating of the amount of F-GHG from the result of measurement, the utilization and the DRE of each equipment tool can be known.

F-GHG including the by-product exhausted from F-GHG and F-GHG input to the equipment tools are object of the measurement.

$$V_i = \int_0^T C_i(t) \times F_i(t) dt$$

$V_i$ : Gas volume for  $i^{\text{th}}$  gas

$t$ : Measurement timing

$T$ : Total time for measurement

$C_i(t)$ : Concentration for  $i^{\text{th}}$  gas

$F_i(t)$ : Gas flow rate for  $i^{\text{th}}$  gas

### 7.1 Measurement of F-GHG concentration

7.1.1 Generally accepted methods such as FT-IR are used for the measurement of F-GHG concentration.

7.1.2 The emissions from equipment including by-products should be measured for grasping of the F-GHG concentration.

7.1.3 The simple characterization method by FT-IR can be used for the measurement of the F-GHG concentration. The detail of the simple characterization method by FT-IR is shown in section 11 Referenced Document ( 1) Simple Method for PFC Characterization using FT-IR Rev 2.20 ).

### 7.2 Identification of F-GHG flow rate

7.2.1 The method for the identification of total flow amount are

- 1) actual measurement.
- 2) sum of all input gas flows.
- 3) calculation from the result of measurement of the gas concentration at outlet of equipment, under the condition of inactive gas (that does not change its quantity inside of equipment) by fixed flow and concentration at inlet of equipment is supplied.
- 4) calculation from the result of measurement of the gas concentration at outlet of equipment, under the condition of F-GHG such as CF<sub>4</sub> by fixed flow and concentration is supplied. However, the caution should be paid at the use of degradable gas like CF<sub>4</sub> as follows. On condition that there is the possibility of reaction in the equipment, the gas is inputted from after equipment where the temperature properly goes down. On condition that there is no possibility of reaction in the equipment, the gas is inputted from the inlet of the equipment.

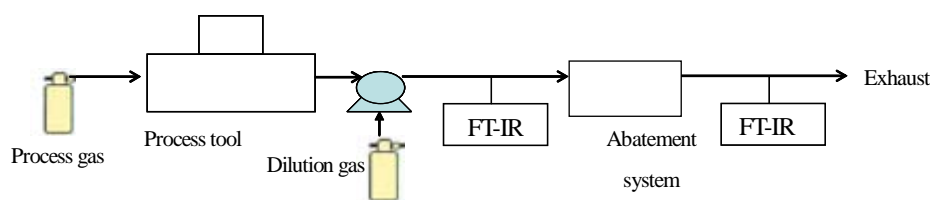
7.3 Identification of F-GHG flow time

7.3.1 The F-GHG flow time can be identified by the time which input gases are flowing, as follows

- 1) Actual measurement time.
- 2) Duration of gas turn on.

7.4 System Configuration

Typical configuration of measurement is shown in Figure 7.4-1.

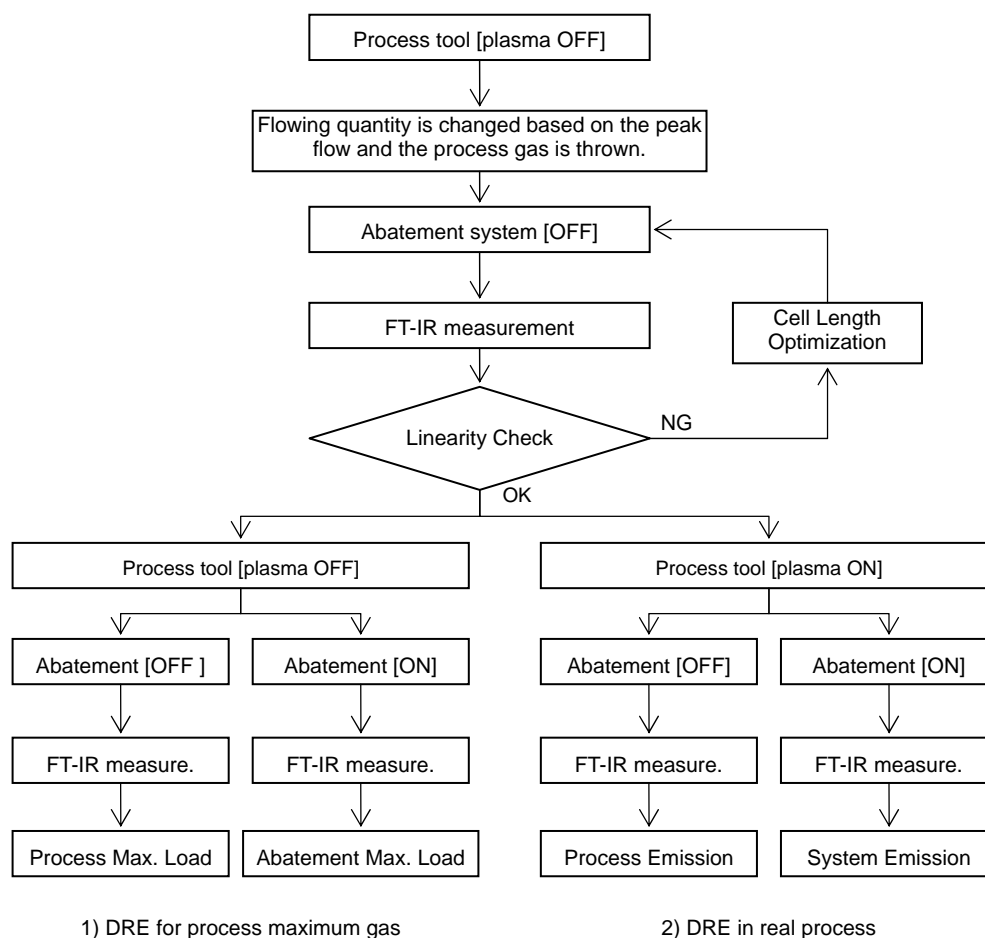


**Figure 7.4-1 Typical configuration of measurement**

7.5 Scene to be measured

A measurement sequence example is shown below.

Details of each step are discussing in following sections.



**Figure 7.5-1 A measurement sequence example**

## 7.6 Identification of the amount of F-GHG from and to process tool

7.6.1 The amount of each input F-GHG is calculated from input flow rate, flow time, and concentration for each input gas identified.

7.6.2 The amount of each F-GHG in exhaust is calculated from exhausted flow rate, flow time, and concentration for each gas identified.

7.6.3 The utilization of F-GHG is calculated by the following formula from the amount of F-GHG input to and exhausted from process tool.

$$\text{F-GHG utilization} = 1 - (\text{amount of exhausted F-GHG}) / (\text{amount of F-GHG input})$$

The recipe must be selected as the measurements of every gas supplied to process tool are implemented. If all F-GHG supplied in the tool could not be covered by a single recipe, the measurement to all of F-GHG types supplied in the tool is accomplished by measuring with several recipes.

7.6.4 At least 5 wafers are processed at the measurement.

7.6.5 The utilization is calculated through all gas flowing period.



7.6.6 The measurement of total exhaust flow amount is actual measuring and adds up individual input gas flow amount. Since the gases such as dilution N<sub>2</sub> of the pump don't change the volume in the process, and occupy most part of exhaust, the volume change of process gases can be ignored.

7.6.7 Precautions at measurement of CVD cleaning

7.6.7.1 The measurement should be done at cleaning after deposition under the actual operating condition, since the deposition in the chamber affects the F-GHG emissions including by-product.

7.7 Identification of the amount of F-GHG to and from an abatement system

7.7.1 The amount of abated F-GHG is calculated with the input flow rate, the flow time, and the concentration for each input gas according the same method as for a process tool

7.7.2 DRE is calculated by the following formula.

$$\text{DRE} = 1 - (\text{unabated F-GHG volume}) / (\text{F-GHG volume to be abated})$$

or

$$\text{DRE} = 1 - (\text{concentration of the exhausted F-GHG}) / (\text{F-GHG concentration to be abated})$$

7.7.3 The recipe must be selected as the measurements of every gas supplied to process tool are implemented. If all F-GHG supplied in the tool could not be covered by a single recipe, the measurement to all of F-GHG types supplied in the tool is accomplished by measuring with several recipes.

7.8 Characterization method for DRE of plasma type abatement system

7.8.1 DRE is calculated by the following formula from the amount of F-GHG in the exhaust at plasma on/off.

$$\text{DRE} = 1 - (\text{F-GHG volume at plasma on}) / (\text{F-GHG volume at plasma off})$$

or

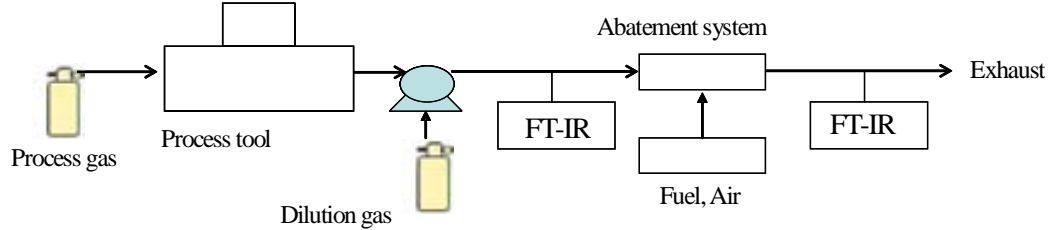
$$\text{DRE} = 1 - (\text{F-GHG concentration at plasma on}) / (\text{F-GHG concentration at plasma off})$$

7.9 Characterization methods for DRE of combustion type abatement system

7.9.1 Since total amount of gases such as fuel, oxygen and air, supplied to combustion unit is large, F-GHG concentration is relatively low due to dilution effect. It is necessary to take care of selecting an appropriate gas cell length.

The amount of F-GHG, air and fuel (become exhaust gases after burning) supplied to abatement system shall be grasped.

F-GHG characterization should be conducted at outlet of the abatement system under combustion and non-combustion, or at inlet and outlet of the abatement system under combustion. Measurements under non-combustion are dangerous when the exhaust includes fuel gases.



**Figure 7.9-1 Schematic diagram of measurement at combustion type abatement system**

#### 7.10 Characterization methods for DRE of heater type or catalyst type abatement system

7.10.1 F-GHG characterization should be conducted at inlet and outlet of the abatement system or at outlet of the abatement system with the heater on/off.

7.10.2 DRE is calculated from input F-GHG volume to the abatement system and emitted F-GHG from the abatement system or emitted F-GHG volume with the heater on and off.

7.10.3 DRE is calculated from the ratio of emitted F-GHG volume with the heater on and off.

$$\text{DRE} = 1 - (\text{emitted F-GHG volume at the heater on}) / (\text{emitted F-GHG volume at the heater off})$$

#### 7.11 Methods of DRE for adsorption type or filtration type abatement system

7.11.1 F-GHG characterization should be conducted at inlet and outlet of the abatement system.

7.11.2 DRE (Adsorption rate, Filtration rate) is calculated from total input F-GHG to the abatement system and emitted total F-GHG from the abatement system.

$$\text{DRE} = 1 - (\text{exhausted F-GHG volume}) / (\text{input F-GHG volume})$$

#### 7.12 Characterization methods of DRE for collection type equipment

7.12.1 F-GHG characterization should be conducted at inlet and outlet of the collection equipment.

7.12.2 DRE (Collection rate) is calculated from total input F-GHG to the collection equipment and emitted total F-GHG from the collection equipment.

$$\text{DRE} = 1 - (\text{emitted F-GHG volume}^*) / (\text{input F-GHG volume})$$

\* Emitted F-GHG volume is equal to non-collected F-GHG volume.

#### 7.13 Characterization methods of DRE for other type equipment

7.13.1 In the case of other equipment we described above DRE is calculated from total input F-GHG to the abatement system and emitted total F-GHG from the abatement system.

7.13.2 The case of equipment designed for F-GHG abatement other than we described above, DRE is calculated from total input F-GHG to the abatement system and emitted total F-GHG from the abatement system.

## 7.14 By-product

7.14.1 When process tools are used plasma reaction, DRE is measured following two cases.

- 1) At plasma off of process tool (DRE for process gas).
- 2) At plasma on of process tool (simultaneous DRE for process gas and by-products).

### 7.14.1.1 The measurement method of process tool plasma off

The measurement is implemented process tool plasma off and actual recipe process gas condition. Or, when the maximum load condition on the process is clear, it is possible to represent it by the result of a measurement of the maximum load condition.

### 7.14.1.2 The measurement method of process tool plasma on

The measurement is implemented process tool plasma on and actual recipe process gas condition. Or, when the maximum load condition on the process is clear, it is possible to represent it by the result of a measurement of the maximum load condition.

## 7.15 Others

Water spectrum on FT-IR should be subtracted for accurate characterization when the scrubber is connected before measurement point and the water spectrum influences the result strongly.

## **8 Characterization Timing and Frequency for F-GHG Emissions**

This chapter describes the timing of characterization to understand the F-GHG emissions from the tools and the possibility (method) of frequency reduction of characterization.

### 8.1 Characterization Timing for F-GHG Emission

Timing of characterization should be determined from considering the shift during operation of the tool and the change or improvement of tool conditions.

8.1.1 Basically, characterization should be conducted at the timing of application of this guideline, installation, process condition change, application of new process recipe, and just before and after maintenance for the process tool and/or the abatement system.

8.1.2 In addition, characterization should be conducted when the changes of the operating conditions occurred, that is expected the utilization of the process tool or DRE of abatement system will decline.

Examples:

Process recipe change (change of process gas, for example)

Modification of the process tool or abatement system

### 8.2 Possibility of the frequency reduction for the measurements for each tool

8.2.1 When the recipe having the lowest utilization is recognized, we can represent the result with the recipe.

8.2.2 Some tools have recipes of different load of F-GHG. In the case, the biggest load of F-GHG recipe should be chosen to measure. In this case the F-GHG emissions characterization would be reported larger value than actual value (utilization has smaller value).

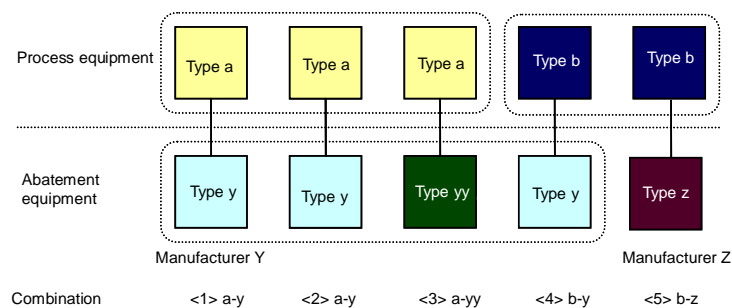
8.2.3 The case of process tools, the number of measurements can be reduced, when the performance stability of the process tools could be confirmed by that the utilization and emissions of byproducts. are constant.

8.2.4 If the relationship between the fluctuation and utilization/DRE is confirmed,, the lowest value should be applied to reduce the frequency of the measurement. For example, in the case of abatement systems, when a certain improvement of DRE after maintenance could be demonstrated by the measurement both before and after maintenance, DRE measurement after maintenance can be reduced.

### 8.3 Possibility of measurement object reduction

8.3.1 The constitution of tool and abatement system are operated as a unit, outlet of the unit would be measured.

8.3.2 When the recipe and constitution of tool and abatement system are the same and these tool and abatement system are properly managed, and the result of either case would be applied. In the Figure 8.3-1, as only <1> and <2> are the same, either of them would be measured.



**Figure 8.3-1 Combination of process tool type and abatement system type**

### 8.4 Risk with the reduction of the measurement frequency

8.4.1 Many reporting rule require that DRE/utilization keep the given level. Since the reduction of measurement frequency makes the term longer, when DRE/utilization did not satisfy the given level, disadvantageous emissions should be reported tracing back a long period.

## 9 Characterization Data Management

Results of characterization should be recorded to verify.

Information of the tools or the abatement systems

Process information

Recipe used at the time of data characterization

Total process run numbers or hours after the previous dry cleaning of process chamber

Measurement information

Measurement instrument name

Manufacturer's name

Measurement method

Calibration data

All data for characterization

Recommended methods to verify reliability of F-GHG emissions characterization data as to the tools, the abatement systems, the measurement instrument or the measurement condition

Contact information for an inquiry

## 10 Revision History

## 11 Referenced Document

- 1) Simple Method for PFC Characterization using FT-IR Rev 2.20
- 2) Guideline for Environmental Characterization of Semiconductor Process Tool  
Revision 2 (ISMI Technology Transfer #06124825B-ENG (December 9, 2009))
- 3) Protocol for Measuring Destruction or Removal Efficiency (DRE) of Fluorinated  
Greenhouse Gas Abatement system in Electronics Manufacturing

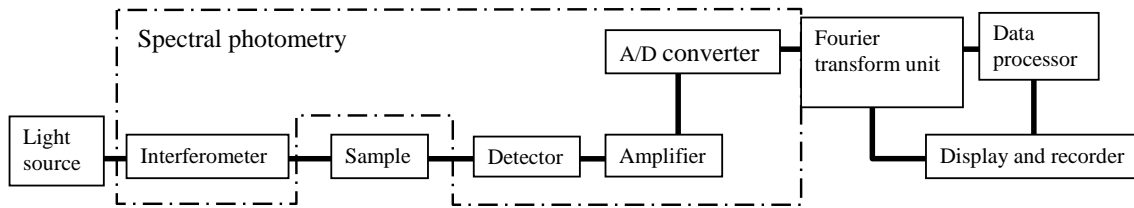
## 12 Related Information

### 12.1 Outlines of measuring instruments

FT-IR and QMS are shown below as representatives of measuring instruments.

#### 12.1.1 Fourier Transform Infrared Spectrometer

Figure 12.1-1 shows FT-IR configuration. FT-IR is comprised of a light source, a sample stage, spectral photometry (an interferometer, a detector, an amplifier, and an A/D converter), a Fourier transform unit, a data processor, and a display and recorder.



**Figure12.1-1 Configuration of FT-IR**

FT-IR measures the interferogram of the sample transmitted light in a Michelson interferometer and gets the absorption spectrum of the sample by Fourier transforming the interferogram. Each F-GHG concentration in the sample is measured by analyzing the spectrum data.

(1) Attention on the measurement

- 1) Appropriate gas cell length should be selected at the measurements referring to the Table 12.1-1 Length of gas cell and measurable range (ppm) shorter cell length should be used when we measure high concentrations, and longer cell length those of low concentrations. In addition, the sample gas concentrations should be moderate appropriate range by diluting with such as nitrogen gas.

**Table 12.1-1 Length of gas cell and measurable range (ppm)**

Gas Name	Cell Length: 1 cm		Cell Length: 10 cm		Cell Length: 4 m	
	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit
CF <sub>4</sub>	3	40000	0.3	4000	0.008	100
CHF <sub>3</sub>	14	40000	1.4	4000	0.035	100
C <sub>2</sub> F <sub>6</sub>	10	40000	1.0	4000	0.025	100
C <sub>3</sub> F <sub>8</sub>	5	50000	0.5	5000	0.013	125
C <sub>4</sub> F <sub>8</sub>	25	18000	2.5	1800	0.063	45
SF <sub>6</sub>	4	3400	0.4	340	0.01	8.5
NF <sub>3</sub>	27	30000	2.7	3000	0.068	75
CO	500	30000	50	3000	1.25	75
CO <sub>2</sub>	10	13500	1.0	1350	0.025	33.75
COF <sub>2</sub>	100	10000	10	1000	0.25	25
OF <sub>2</sub>	2550	80000	255	8000	6.375	200
HF	125	72000	12.5	7200	0.313	180
SiF <sub>4</sub>	45	5700	4.5	570	0.113	14.25
SO <sub>2</sub>	15	12600	1.5	1260	0.038	31.5
NO	1100	50000	110	5000	2.75	125
NO <sub>2</sub>	140	14000	14	1400	0.35	35
N <sub>2</sub> O	360	15000	36	1500	0.9	37.5

- 2) Some spectra may interfere mutually at measurement of gases containing multiple F-GHGs. For minimizing quantification error, absorption spectrum for qualification should be selected not to be

interfered by other spectra. Measurement without the range which can keep linearity between absorption spectrum of infrared and concentration quantified, the results may have large error.

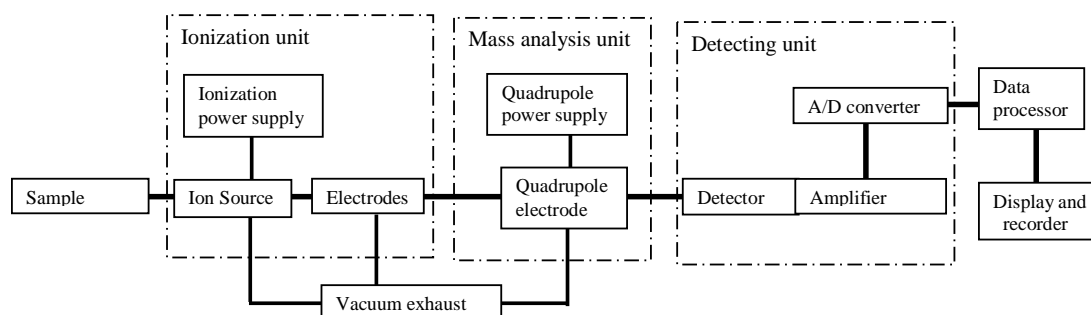
- 3) A simplified method for PFC measurement by FT-IR (Simple Method for PFC Characterization using FT-IR) is recommended for easy selection of an appropriate spectrum and linearity range. In this guideline, we strongly recommend the use of “Simple Method for PFC Characterization using FT-IR” to aim the generalization of the methods which can identify the process gases include byproduct and wavelength of measurement.

Therefore, in this guideline, we specifically describe “Simple Method for PFC Characterization using FT-IR”.

- 4) “A simplified method for PFC measurement by FT-IR” enables to set appropriate conditions for highly accurate measurement. Because it provides information of byproduct gas, an appropriate IR absorption spectrum for measurement and linearity range based upon input of a process gas to be used.

#### 12.1.2 Quadrupole Mass Spectrometer

Figure 12.1-2 shows QMS configuration. QMS is comprised by an ionization power supply, an ion source, electrodes, a quadrupole power supply, a quadrupole electrode, a vacuum exhaust, a detector, an amplifier, an A/D converter, a data processor, and a display and recorder.



**Figure 12.1-2 Configuration of QMS**

QMS mechanism is as follows.

- 1) Sample gas is ionized.
- 2) The Ion beam is separated depending on mass/electric charge ratio by an electric field and a magnetic field.
- 3) The ratio of each molecule of the whole sample gas is estimated.

#### 12.2 Outlines of the monitoring

Instruments other than we mentioned above are not recognized for a measuring instrument of F-GHG now.

When an applicable technique appeared with the progress of usage or technology as a monitor for management of F-GHG, we'll list it below.



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