Mongolia
The Air Quality Department of Capital City
(AQDCC)

Capacity Development Project for Air Pollution Control in Ulaanbaatar City Mongolia

Final Report Technical Guidelines

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SUURI-KEIKAKU CO., LTD

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Capacity Development Project
for
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in Ulaanbaatar City, Mongolia

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Flue gas Monitoring Protocol

1. Purpose of Protocol (Protocol Necessity)

Mongolian generally use coal combustion to heat water that is necessary for homes and business activities. Thermal power plants, small boilers (i.e. HOB & CFWH) and home stoves supply the hot water.

Thermal Power plants provide the majority of the hot water needs in Ulaanbaatar City through the large web of supply system. In the area outside of this web, a small scale boiler in each city block supplies the hot water to the surrounding homes and public facilities (e.g. schools and hospitals). Many small scale boilers in the city form the local heating system to meet the needs in such area. In the area where there is no local heating system, the hot water needs are met by the use of Coal Stove at each home.

Increased air pollution in winter is believed to be caused by the coal combustion at these stationary sources. Thus the flue gas monitoring at these stationary emission sources is the necessary first step in the air quality improvement.

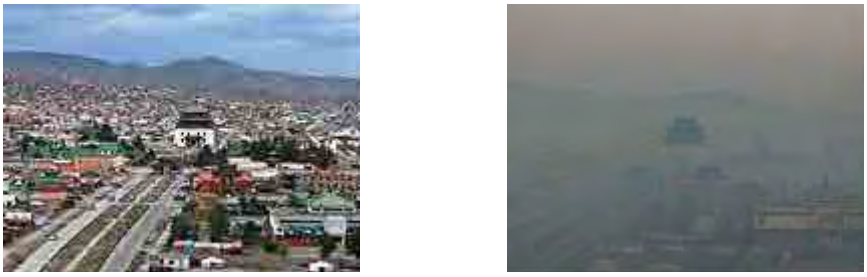


Figure 1-1 City View (Left – in Summer, Right – in Winter)

Unlike fuel oil, coal combustion characteristics are not uniform, producing varying gas characteristics over time (e.g. varying temperature, pressure, amount of pollutants). The characteristics are also influenced moment by moment by other variables such as equipment, structure, operating condition, and hot water demand.

Flue gas characteristics can be quite different from a facility of one area to a facility of another area even if the same type of boiler is used by two facilities. A seasonal difference presents different gas characteristics even at the same facility: e.g. less hot water demands during an early winter vs heavy hot water demands in the midst of a severe winter. Therefore, it is not easy to obtain the typical value of the flue gas concentration from a boiler simply by making a flue gas measurement.

Therefore, this project provides the Monitoring Activity Directive (Monitoring Protocol) describing how to obtain the so-called typical values from the flue gas monitoring at a boiler or a stove.

2. Extent Covered by Monitoring Protocol

The purpose of this manual is to provide the activity directives for measurements and calculations in order to obtain representative pollutant concentration values and emission factors by analyzing the flue gas monitoring results.

This protocol assumes that there are three distinguished stationary source scenarios to monitor the flue gas: Thermal Power Plants, HOBs, and Ger Stoves.

This manual covers the types of monitoring equipment, the types of boiler facilities, various operational conditions (e.g. the availability of a fan), the sampling timing (e.g. while the fan is ON or OFF), the coal feeding timing and variations, and the calculation methods to obtain representative values.

The target of this manual is the coal burning, small type, hot-water supply boilers called “Heat Only

Boiler (HOB)" whose number is estimated to be approximately 200 existing in Ulaanbaatar. They are medium sized, heat-supply equipment and are also classified as small boiler equipment. The purpose of the monitoring is to measure and characterize the flue gas from these HOB chimneys. The other stationary emission sources (i.e. Thermal Power Plants and Ger home stoves) do not change their flue gas characteristics as much as HOBs, thus we consider that the monitoring protocol for HOB's will be compatible to that for the other sources. Thus, the detailed procedures for the other sources are described in the corresponding guidelines.

Also described are notes and cautions for the comparison of the actually collected data against the emission standard values in MNS.

Elements that can influence the flue gas characteristics are numerous so that it is impractical to summarize all monitoring protocols on a single sheet. Therefore, this manual shows various measurement protocols by varying the protocol details for each of the patterns we have categorized.

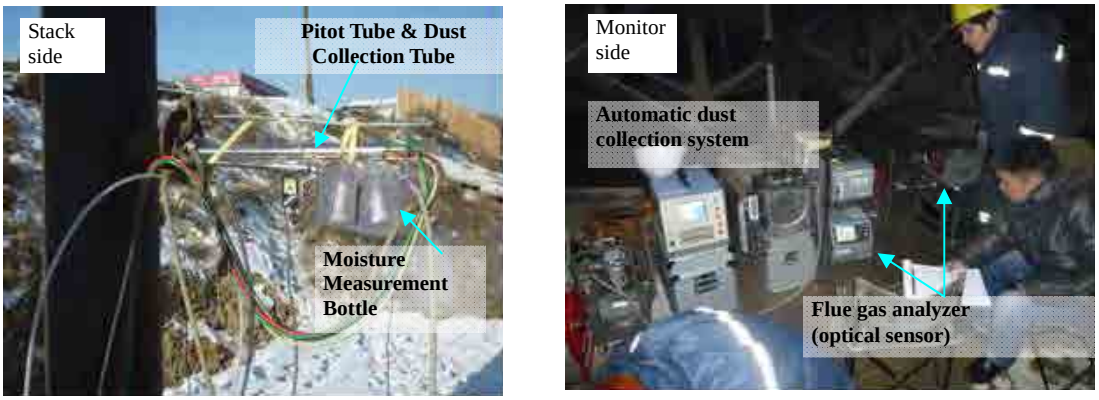


Figure 2-1 Flue gas Monitoring Scene

3. HOB's

To ease readers' understanding toward the protocol, we first discuss HOB characteristics in Section 3.

3.1 HOB Use in Ulaanbaatar

The hot water in the area outside the hot water supply network of the thermal power plants is supplied by the locally installed, small coal boilers and is mainly used for home heating and cooking. The lack of hot water, therefore, could be a matter of life and death during the severe winter season, thus, the boilers are operated continuously without any break during such season. The capacity of most of such boilers is one (1) MWatts or less.

When one HOB covers one residential area, Hot water is supplied to the residents and smaller public facilities such as schools, hospitals and government offices without any distinction of the targets (e.g. public or private) or the demands. Each house or facility is charged by the amount of water used. Most of such operations are managed and performed by commercial boiler operating contractors.

Companies and merchants (e.g. Grocery Store / Super Markets) who have large facilities tend to have their own boiler for each building that is operated on their own.

Figure 3-1 Feeding Coals into Furnace

Photo 3-2 Example of one HOB Coverage

Seasonal boiler operators who are hired only during long winter seasons in Mongolia to take care of the furnaces feed coal 24/7. HOB's are constantly operated except summer (June through August). Boiler peak operations are during severe winter days from November to March, during which the coal consumption and the flue gas volume increase, which results in high pollutants in the air. The constant HOB operations quicken the furnaces deterioration, thus boilers must be replaced in two to three years normally.

These HOB's in Ulaanbaatar are made in Mongolia, Russia, South Korea, China, Czechoslovakia, and Hungary. Small coal boilers tend to have low energy efficiency and poor flue gas treatment, if any. Especially, Domestic boilers tend to have poorer characteristics, although domestic boilers are getting better by learning from the imported boilers. Sometimes, we find unsuccessful domestic boilers left abandoned.

Facilities without the boiler renewal funding are forced to keep using old boiler types. Domestic manufacturers repair or replace damaged parts such as heat-exchanger tubes. Countries such as United States and South Korea are providing aid to renew the boilers to boilers with high energy efficiency and low emission to improve the air quality.

3.2 Components of HOB System

Boiler facilities consist of three major parts from the gas line point of view as seen in the table below.

Table 3-1 Boiler Flue Gas Line Major Components

Major Components	Details and Components
Boiler	Furnace (Combustion Chamber), Grate, Heat-Exchange Tubes, Hopper (Coal Supply Door), Ash Collector, etc.
Air Supply Fan	Induced Draft Fans, Forced Draft Fans
Flue Gas Processor	Cyclones, Bag-filters, Wet Scrubbers
Smoke Duct	Horizontal or Vertical Smoke Duct
Smoke Stack	Cast iron or Brick
Others	Air Pre-Heater, Air Control Dampers, Metering Coal Hoppers & Chain Grate Stokers, Automated Ash Removal Screws

The small, coal boilers in Ulaanbaatar can be further categorized into six (6) groups of different types of induced fans and flue gas process devices that tend to largely influence the pollutant emission volume from the stacks.

"F" denotes Fan, "HOB" Boiler itself, "S" Emitted gas processor, and "C" Chimney

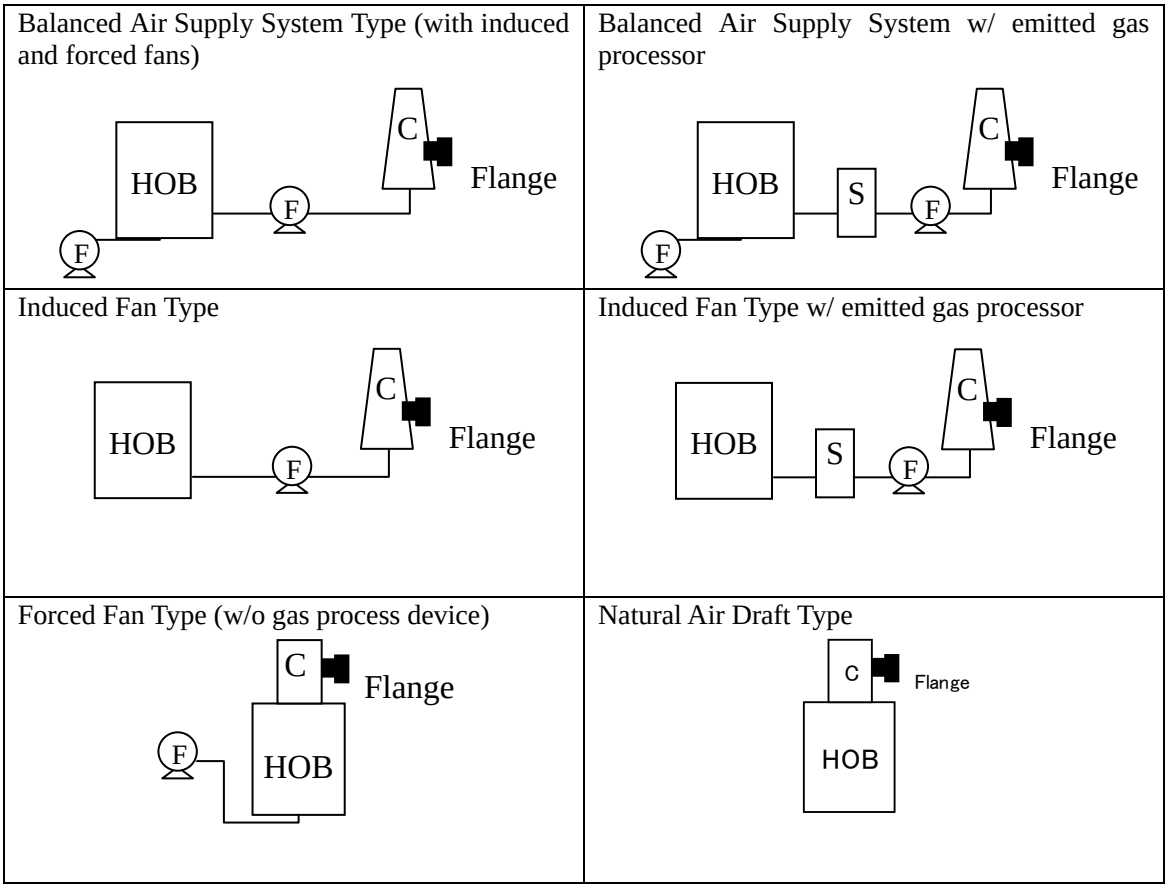


Figure 3-1 HOB Type Categories

3.3 Influencing Elements On Flue Gas Characteristics

Table 3-2 roughly categorizes the elements that influence the measurement values. Items under "Structure" in the table are the structural difference described in Section 3.2. Boiler Operating Condition (including Boiler Use) is another Influencing factor besides the structure.

Table 3-2 Elements that Change Flue Gas Characteristics

	Structure	Operating Condition
Coal Supply	Automated, Manual	Supplying interval, Volume (that relates to the hot water demands), Coal type (chemicals in coal), Coal size
Ventilation	Natural air draft, Induced fan, Forced fan, Balanced fans	ON/OFF timing Damper angle adjustment
Emitted Gas Processor	Cyclone, Wet-type scrubber, Bag filter	Maintenance condition
Others	Boiler Type	Ash raking task (stoking work) Clinker removal work

3.4 Actual Operating Conditions

Boilers are not necessarily kept at the high combustion state always. The boiler state is manually adjusted as required based on the hot water demand by the users.

When the hot water demands are low, the boiler operator keeps the boiler in the oxygen-starving condition by normally stopping the air supply. They monitor the water temperature that comes back from the users, and when the temperature goes below 60℃ (or 70℃ in some boilers), then they turn on the fans or feed more coal. They must also pay attention to the sulfuric acid dew point and decide the operational actions accordingly.

When the boiler fire is extinguished, the boiler temperature drops rapidly. Even when the fire is restarted, it takes several hours to stabilize the furnace temperature. The boiler fire is never extinguished for any reason unless there is a boiler trouble or the electricity is out. The power outage stops the air supplying fans such that the boiler will starve for the oxygen and the fire will go out. Except the natural air-flow type boilers, HOBs can operate only with the help from electric fan(s) supplying the air (oxygen) and with the help from Thermal Power Plants supplying the electricity.

The type of coal used by HOBs is normally Nalaikh coal (Brown coal or lignite) whose quality and size are hardly uniform. Nalaikh coal is low quality, has low carbon efficiency, and contains sulfur and water much higher than Baganuur coal. Each boiler chooses the size of the coal to purchase among lump coal, crushed coal (a few cm) and powder coal.

Large lump coal does not easily light up, which results in the incomplete combustion. So the boiler operators crush the large lumps to a size of a fist before feeding to the furnace.

The combustion profile is different between lump coal and powder coal. Lump coal does not combust easily and tends to generate incomplete combustion and higher amount of CO when it is newly fed into a boiler, but produces longer, steady heat once lit. On the other hand, powder coal ignites fast and also burns through fast which results in much better complete combustion but results in more frequent feeding. The dust concentration and water content in flue gas will increase when new coal is fed and when ash is raked.

Harmful material content in the flue gas varies by the combustion condition of the furnace and the boiler operating circumstances including the operator actions. There is no identical concentration variation pattern among boilers.

Even for a given boiler, the average concentration varies by the hot water demand (e.g. the demand is quite different between November and January) and by the resulting coal volume and feeding pattern difference. In other words, an average concentration of the flue gas cannot be determined even if the boiler types are the same. Therefore, an average concentration of a boiler must be measured and obtained for each unique combination of the influencing variables (e.g. hot water demand). It is also helpful to understand the variation range of each influencing factor in relation to each element concentration in order to obtain the average emission concentration of the boiler.

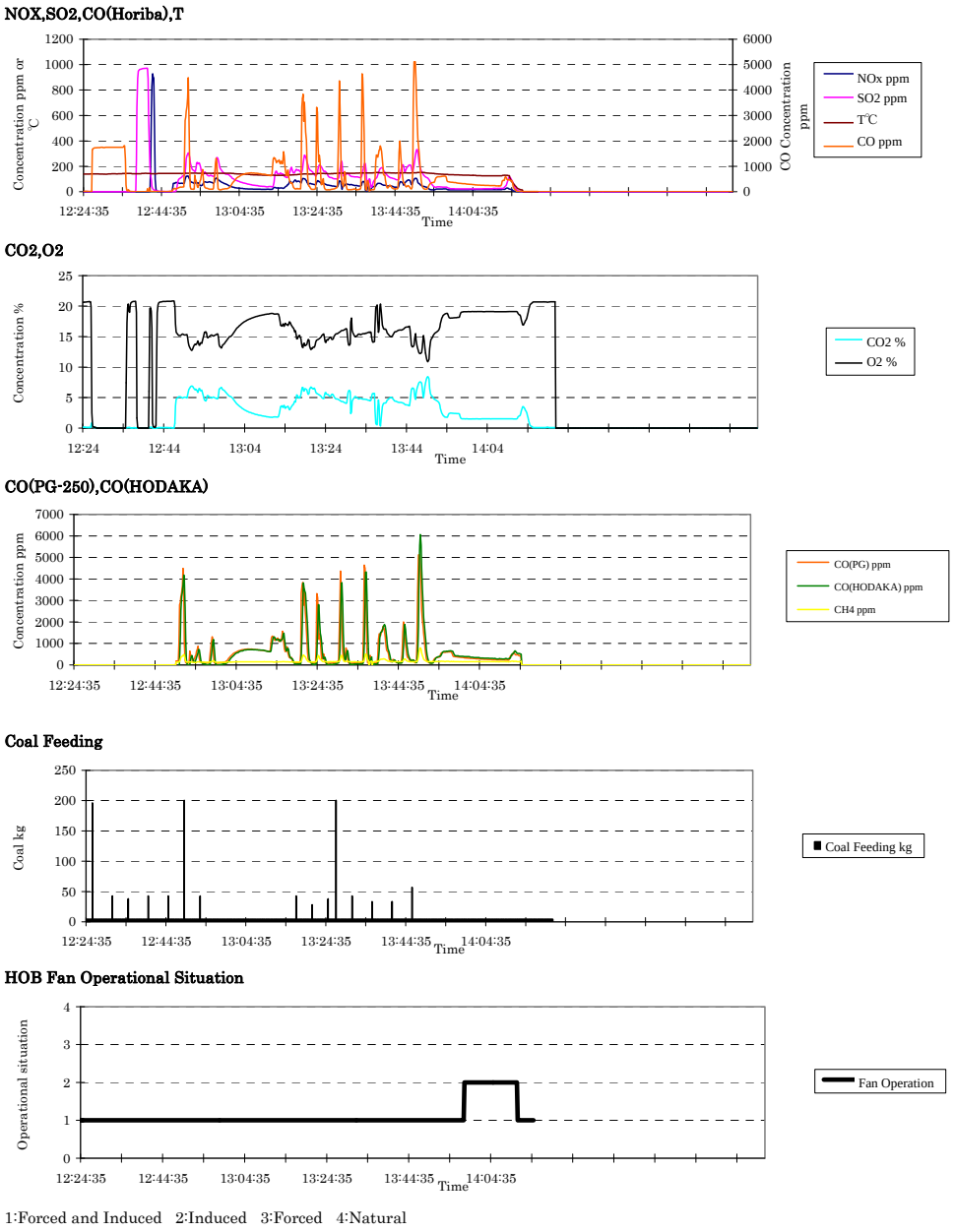


Figure 3-2 Flue gas Concentration Variation (Example)

Almost every one of the entire HOB operators in Ulaanbaatar manually throws coal into his boiler furnace at every feeding. An HOB Boiler operator with a large hot water demand hardly has a break between the cyclic tasks of “Coal feeding”, “Ash raking”, and “Clinker removal”.

There are automated feeding boilers besides the manual feeding boilers. Such boilers automatically perform the feeding, combustion control, and ash and clinker removal. Thus, the boiler operator’s load is lighter. However, due to the high procurement cost of automated boilers, there aren’t many of them deployed. Certain boilers from Hungary are capable of storing a large amount of coal in the coal hopper that sits on top of the boiler, thus, the coal is slowly fed into the boiler over a few hours which reduces the boiler operator’s load.

Figure 3-3 Manual Feeding

Figure 3-4 Automated HOB

There are many types of HOB coal boilers. The common task characteristics of the operators are a) to judge the hot water demand volume by reading the hot water temperature and the furnace pressure meters, b) to judge the combustion status by visually observing the furnace combustion, and c) to operate the boiler (by controlling the coal feeding, ash stirring and clinker removal).

However, there are a number of facilities with malfunctioning temperature sensors and/or pressure sensors so that the boiler operators often rely on their own intuition and experience to operate. So it is not rare to have slightly different operating methods (thus different flue gas emission) by different operators even for the same amount of the hot water demand at one facility.

4. Measurement Protocol

This section describes various aspect of the flue gas monitoring such as the measurement methods, equipment, sampling timing and calculation procedures.

4.1 Operational Consideration

In order to obtain a representative value (values) of harmful pollutant concentration from the flue gas of a boiler, it is helpful to obtain the measurements from the boiler that is operated under a typical combustion pattern. Since the most severe pollution occurs in winter, the boiler should be operated at an environment that produces close to the peak load in the most severe winter.

(For example, assume a boiler error occurred and the fire is extinguished. Thus, the starting point can be the firing point with fresh, predetermined-grade and -size coal of 200 kg to be fed into the furnace. Then the fan is turned ON to supply the air. After 20 minutes of combustion, another feeding of 40 kg coal is added, … etc.)

However, this project does not assign a typical combustion pattern to characterize an HOB boiler with the following reasons:

a) A considerable number of boilers is incapable of conducting a typical combustion pattern.

➢ Such boilers have a very small furnace capacity so that the furnace may break at a prolonged, sustained high combustion condition. Others boilers may have an incompatibility with the coal if we specify.

➢ A boiler in an area with a low hot water demand may not be able to keep supplying the hot water in the prolonged, sustained high temperature condition in the typical pattern even if the boiler may be capable. Or the reverse situation may be true, such that the demand is too much that the typical pattern of the boiler may not supply a sufficient amount of hot water.

b) Data that is obtained from the measurements at a boiler that is running under the typical combustion pattern (which is called Champion Data) may be useful in the characteristics comparison among boilers, but the usefulness of such data is questionable for the measurements and evaluation of the actual flue gas emission.

C) Even if a typical combustion pattern may be obtainable, such a pattern can be established from various patterns obtained by examining a sufficient amount of actual data from repeated measurements of similar conditions. With the current state of nearly no actual measured data from boilers, a typical pattern cannot be established.

Therefore, this project aimed its target in obtaining the highly accurate, measured data as each boiler was operated under a condition during a given date of our visit, rather than setting a typical combustion pattern of all boilers. This enabled us to obtain the flue gas emission status under the actual operating condition.

"Representative Value" here means the highly accurate value to be calculated using a highly accurate measurement technique to monitor the flue gas emission from a boiler under the maximum or nearly maximum demand during a severe winter.

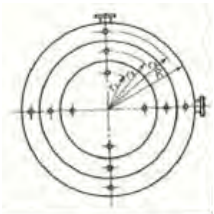
Therefore, the monitoring protocol consists of the measurement methods and procedures in order to obtain the highly reliable, accurate measurement values by considering the operating conditions of the day.

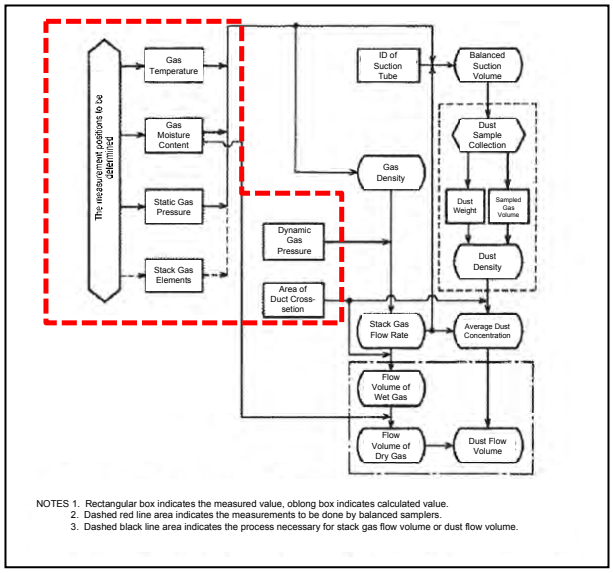
4.2 Monitoring Items and Methods

This document uses Japan Industry Standard (JIS) as its applicable standard. Its overview is shown in Table 4-1.

Table 4-1 Flue gas Monitoring Items, Applicable Standard/Method & Range (Overview)

Items to Monitor	General Collection/Monitoring Methods	
Gaseous Matters	Applicable Standards / Methods	Monitoring Range of Concentration
SO2	JIS B 7981 / Infrared absorption	0 ～ 1000 ppm
NOx	JIS B 7982 / Chemiluminescence	0 ～ 1000 ppm
CO	JIS B 7987 / Infrared absorption	0 ～ 5000 ppm（for low concentration） 0 ～ 5 %（for high concentration）
O2	JIS B 7983 / Galvanic electrode	0 ～ 25 %
CO2	JIS B 7986 / Infrared absorption	0 ～ 20 %
Unique Characteristics of Monitoring Method	Flue gas analyzer should use an optical sensor to analyze multiple gas components automatically, simultaneously and continuously although the O2 sensor can be a chemical type. Flue gas analyzer should not use chemical sensors since the sensors will degrade its performance due to the prolonged exposure to the gases, and therefore, it is not suitable for a continuous operation. The sampled data is collected and outputted to the data logger on site every few seconds, and is accumulated over several hours continuously. The stored data is post-processed by a computer at a later date.	

Dust (temperature, pressure, moisture and flow)	Applicable Standards: JIS Z 8808
Unique Characteristics of Monitoring Method #1	Dust in the flue gas is collected through the silica filter. The weight of the sampled dust and the collected air volume are used to calculate the dust concentration. The entire particulates that are collected by the filter are the sample targets but not the condensed particulate. <Collection Procedure> Measurement point is selected inside the duct cross-section based on the regulated method.  Before sampling begins (preliminary measurements), always measure the flue gas temperature, pressure (flow rate), moisture, and gas components. The dust sampler is installed at the pre-determined point within the duct for measurements. At each measurement point, sample (suck in) the flue gas at the rate equal to the flue gas flow speed (Isokinetic Sampling).

<table>
<tr><td></td><td>Block Diagram of Dust Sampling Method
 
</td><td></td></tr>
<tr><td>Unique Characteristics of Monitoring Method #2</td><td>・Manual sampling method (Ordinary type)
Based on the results from the preliminary measurements above, the dust sampling condition is calculated on a PC. The sampling device is set up based on the calculation results. Only then the sampling begins. The sampling suction speed, isokinetic sampling speed, must be adjusted manually to match the dust flow rate.</td><td>・Automatic sampling method (Dynamic pressure balanced type)
No preliminary measurement is necessary (moisture is measured separately). The flue gas condition is automatically monitored and calculated to provide a dynamic control of the gas suction speed, which results in the faster and more accurate control than manual type.</td></tr>
</table>

4.3 Overview of Monitoring Equipment

At the stationary sources, the air pollutants are mainly emitted out of the stacks. The sampling and monitoring equipment used to analyze the flue gas at such locations are shown Figure 4-1.

There are two group of equipment: Devices that measure the material concentration, and devices that monitor the flue gas conditions.

Refer to the technical manuals for the operation and maintenance of the equipment. This document will not describe the details of the equipment operation.

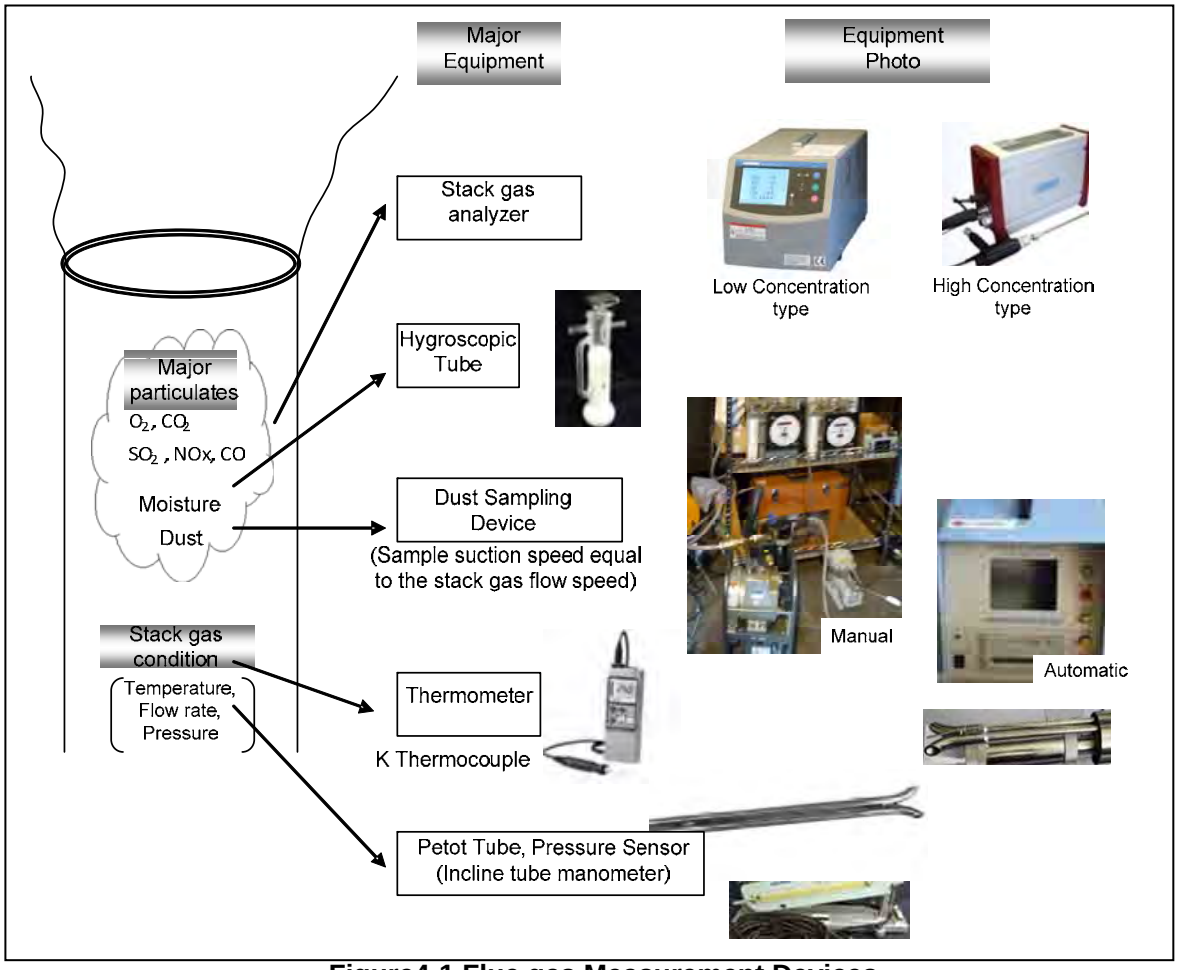


Figure4-1 Flue gas Measurement Devices

4.4 Preparation Prior to Measurements

As seen in Appendix 1, the variation pattern of flue gas concentration is unique at each boiler and none are alike. Therefore, it is essential to obtain the boiler operation information that influences the concentration variation prior to measurements by communicating with the operators in order to calculate the representative values at each boiler (see details in Appendix 2).

・Coal feeding, type, weight, feed timing
・Fan equipment: ON/OFF and timing
・Ash raking, Ash/ Clinker/ Slug removal timing
・Scrubber type, fly ash cleanup timing
・Hot water: Name of the demand organization or individual, approx. size, and the maximum temperature of the supplied water

After receiving information from the boiler operators, generate sampling plans before starting the actual measurements.

You must know in advance when the operational conditions change and what may happen based on the changes as you make measurements. Flue gas samples and measurements should also be taken coincidentally with operational changes. Refer to the "Flue gas Measurement Guideline" for the measurement device installation.

4.5 Timing to measure and sample

This section describes basic operation examples and suitable sampling timing for each example. Also describes how to determine appropriate sampling timing for boilers with complicated combustion patterns.

Refer to Section 4.6 for the relationship between the fan ON/OFF condition and the sampling timing. (Note: The flue gas concentration varies greatly based on the Fan ON/OFF condition, thus the sampling timing and method must change accordingly.)

4.5.1 Basic Sampling Timing (Manual Coal Feeding and Fan always ON)

Figure 4-2 shows the basic pattern of coal combustion at a HOB (the same case as Example #1 under Appendix 1). The interval between two feedings is several hours which is rather long, and the fan is assumed to be ON always in this case.

One "**Sequence**" is defined here as the duration from one coal feeding to the next.

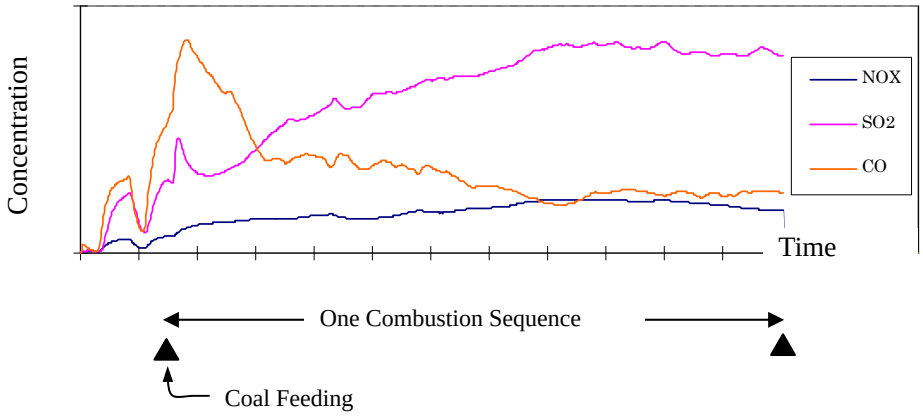


Figure 4-2 Flue Gas Concentration Variation Example Over Time (one coal feeding; Fan ON always)

The basic measurement rules for this case are as follows:

<Basic Measurement Rules>

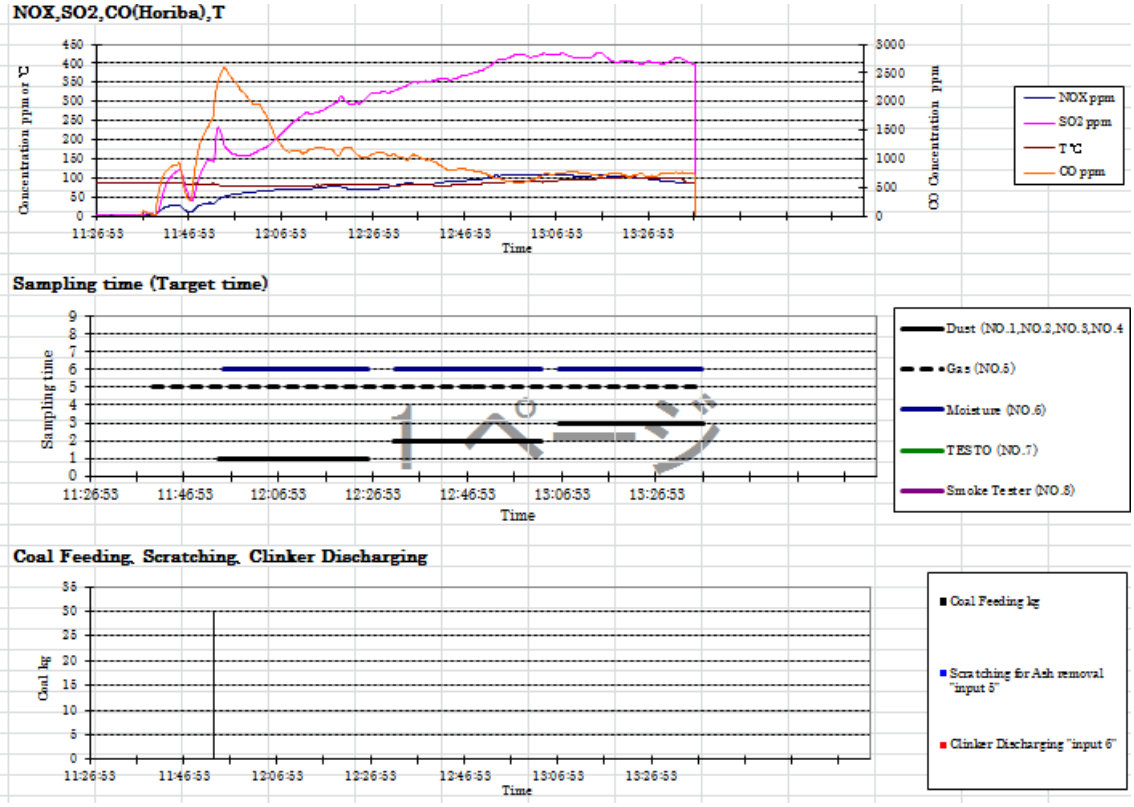
1. The measurement should be done when the temperature is coldest during November to February (in other words, when the hot water demand to the boiler is high). However, no measurement should be taken even during this period if the temperature outside is above -10℃ (because the hot water demand is too low that the coal may not be frequently fed to the boiler).
2. Ensure the regular maintenance such as the cleaning of the flue gas process device to be performed prior to the measurements.
3. Measurement Duration: One Sequence during the boiler being operated.
4. Sample Timing

   Carefully consider the sampling timing of gas, moisture and dust such that the representative values for the measured boiler can be obtained. (Detailed examples are discussed below.)
5. Gas Component Measurements

   Continuously monitor and sample for several hours using a flue gas analyzer prior to a coal feeding to the next coal feeding (Continuous Measurements). In other words, monitor and sample the entire variation of the concentration for one whole Sequence.

   Each measured data of SO2, NOx, CO, O2 and CO2 must be stored into the data logger at least once every 10 seconds.

   A severe incomplete combustion may produce a few percent of CO concentration. A flue gas analyzer to be used must be able to measure such high concentration.



6. Dust Sampling Timing

   Set the sampling duration to be 20 minutes or more and repeat the sampling at least three times

(e.g. the 1st Sampling period to start at the coal feeding when the dust concentration becomes high, the 2nd Sampling period to start when the concentration is medium and starts going lower, and the 3rd Sampling period to start when the combustion becomes lower and during the period of low concentration). The number of sampling should increase for a boiler with a long Sequence time such that one Sequence is finely sampled and analyzed.

If a low dust concentration is estimated based on your judgment by the flue smoke concentration, the sample collection duration can be lengthened more than 20 minutes for one sampling period. However, if a high dust concentration is expected, then the sampling period can be 20 minutes.

It is important to take sampling for more than approximately 70 % of one Sequence duration.

(e.g. Ensure that the total of three sample periods becomes more than 80 minutes for one Sequence of two hours or 120 minutes.)

The measurement start time and end time must be first selected by knowing the operational pattern, which would be one of the important factors in obtaining the representative values (refer to Sampling time in second figure of section 5).

The gas suction speed must be adjusted (not to be too fast) when you expect high concentration of dust and moisture. Also you must pay attention to the sampling duration to be short enough so that the filter would not be torn.

<When You Operate Dust Sampler Manually>

Perform “temperature”, “pressure”, and “moisture” measurements of the flue gas before the dust sampling commences (Operating Environment Pre-Sampling Measurements). The results from the operating environment measurement combined with the gas component measurement results determine the isokinetic suction speed during the dust sampling which is calculated by a personal computer (PC). Under the calculated setup, the sampling activity commences. Once the sampling starts, “temperature” and “pressure” must be measured every minute, and also manually adjust the suction speed accordingly as often as you can to create the isokinetic suction sampling condition.

<When You Use Automated Dust Sampler>

The suction speed adjustment is done automatically, thus no operating environment pre-sampling measurement is necessary. You can perform the dust sampling and moisture sampling in parallel.

7. Moisture Sampling

Moisture concentration is greatest immediately after a coal feeding (evidenced by the white flue smoke). Also white smoke is observed when ash is raked. Sampling must be performed during these periods as well as when white smoke is not observable from the chimney. The sampling timing must be determined to obtain the best representation of the flue gas values of the boiler operation.

8. Record in the field notebook the environmental and operational information during the entire measurement duration (refer to Appendix 4).

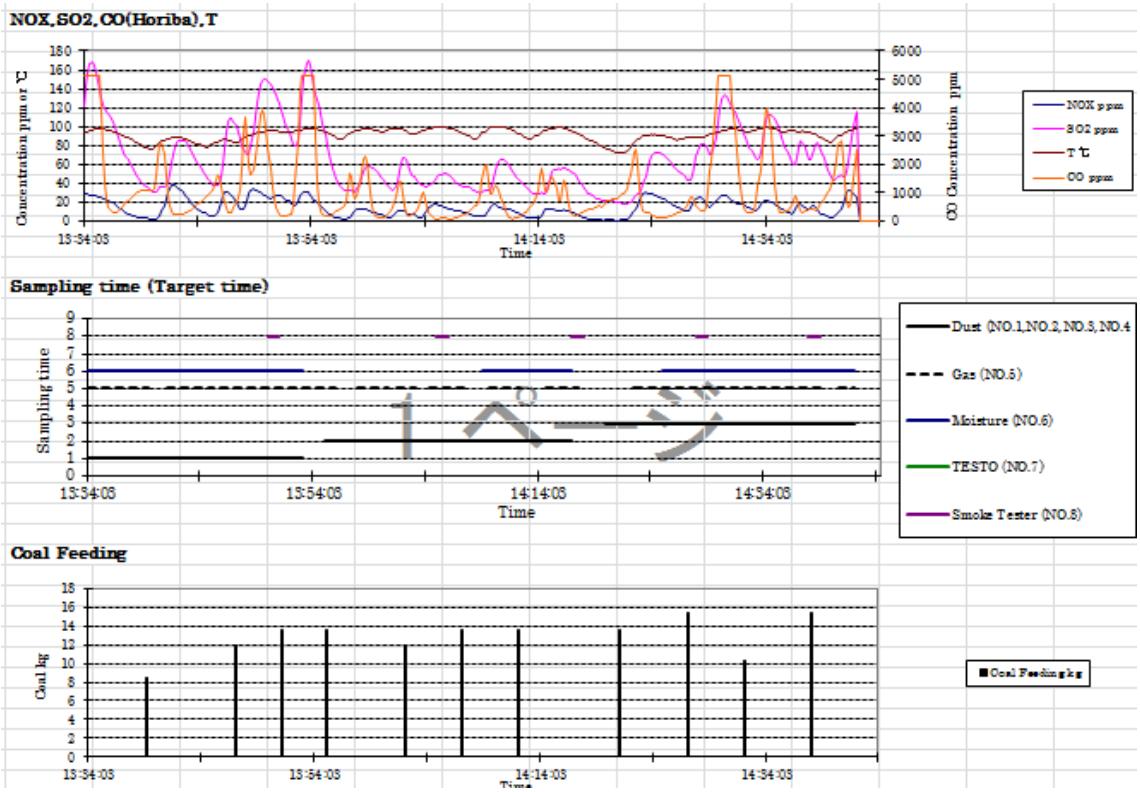
When you operate the dust sampler manually, record the flue gas conditions every minute in the calculation spreadsheet on a PC such as temperature and dynamic pressure.

9. Continue the measurements and sampling even during the boiler operator is raking the ash or removing the clinker, so that you won’t miss the timing when the flue gas concentration becomes high. Make a note of such events also in your field notebook.

10. Stop the measurements and sampling if the boiler facility experiences troubles or operates unusually different from the normal operation since you won’t be able to obtain the representative values.

4.5.2 Example for Frequent Manual Coal Feeding (Fan always ON)

One dust sample period is 20 minutes, but the coal feeding interval is shorter than one dust sampling period in this case.



The sampling duration in this particular case follow the basic rules in Section 4.5.1, and goes beyond one Sequence or goes over the multiple Sequences. This case has multiple coal feedings during one dust sampling period.

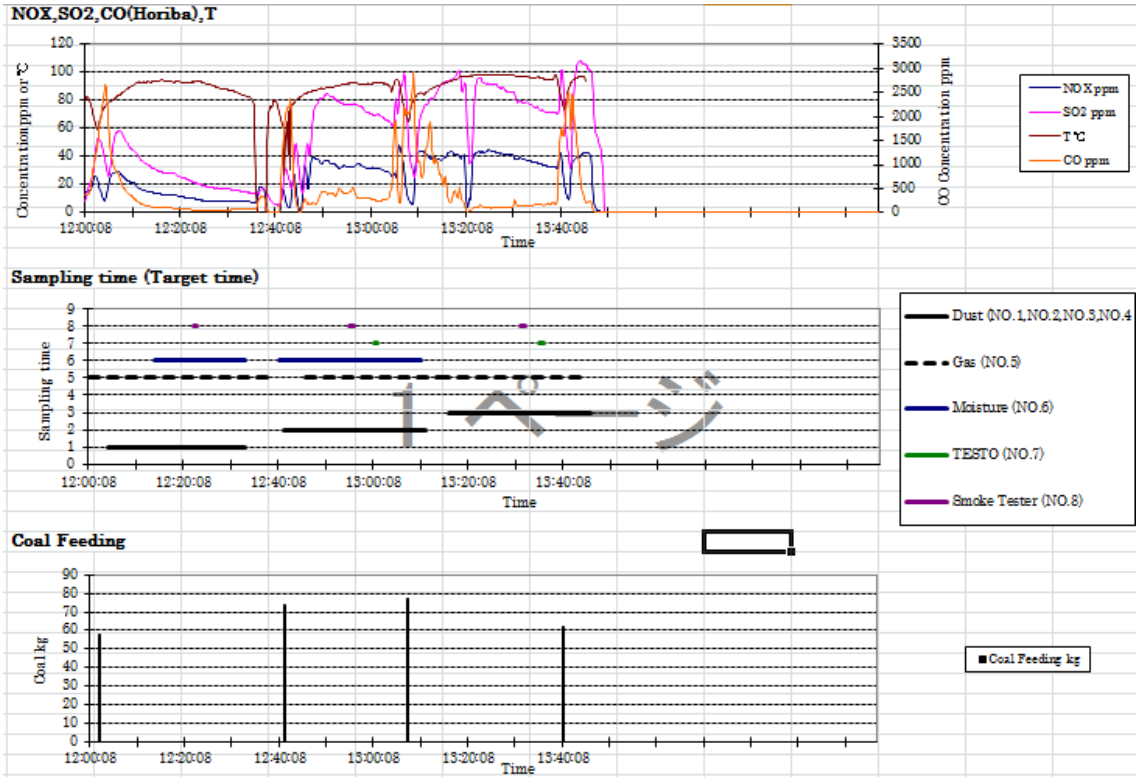
Dust sampling must continue when the coal feedings are repeated regularly more or less and even when there are many coal feedings during one sampling period (refer to the feeding numbers 2, 3, 4 and 7 figures in Appendix 1). It is considered that the calculated values may be close to the average values over three consecutive sampling periods even when the coal feeding timing from one feeding to the other may vary slightly.

4.5.3 Irregular Manual Coal Feeding Timing (Fan always ON)

There can be a case that the manual coal feeding interval is not as frequent as shown in Section 4.5.2, while the feeding intervals are irregular and an interval may be longer sometimes than one dust sampling period of 20 minutes. This case could be caused by a large variation in the hot water demand depending on the time.

It is often difficult to determine a typical Sequence duration in such case. The difference from the basic rule is to adjust the dust sampling duration appropriately as you discuss the boiler operations with the operator.

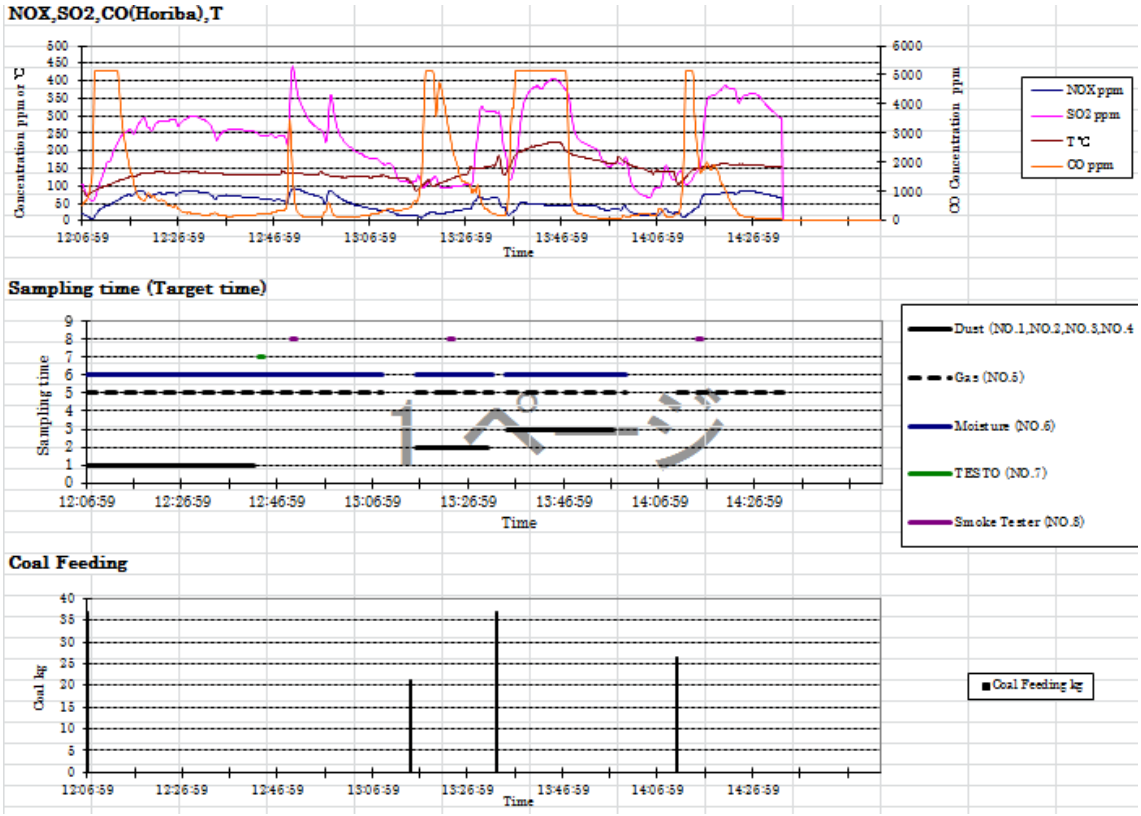
The coal feeding interval in the figure below is either 20 minutes or 40 minutes.



4.5.4 Natural Air Draft (Manual Coal Feeding & No Fan)

A small boiler may not have a fan such that the combustion draws the air into the furnace naturally from outside. Thus the coal combustion variation greatly affects the gas concentration and flow rate.

The hot water demand to such boilers varies greatly by time similar to the case of Section 4.5.3. Thus the dust sampling duration, for example, must be determined appropriately as you discuss the boiler operations with the operator as well.



You must also pay attention to the dust sampling suction speed as the coal combustion nears its end because the flue gas speed goes lower. Because the pitot tube flow speed measurements may not be feasible at a low speed.

The lowest flow speed may be 4m/s if any accuracy is required by a pitot tube. This project, therefore, had to make an exception for boilers with a flow rate of 4 m/s or less and allows the sampling even at 2 m/s flow rate.

When the flow rate goes below 2 m/s, dust sampling must be stopped immediately although you should continue the gas component measurements. During such period, the dust concentration normally goes very low, so we consider that the dust concentration is zero during such period.

When the boiler has a long natural air draft, you can continue sampling at the constant speed (although it is not a isokinetic sampling) and use the data as reference.

4.5.5 Boilers with Automated Coal Supply Mechanism (Fan ON always)

A boiler with an external or internal automated coal supply mechanism supplies coal to the furnace automatically in a steady, constant pace.

a) A boiler with external automated coal supply mechanism (Model example: DZL)

b) A boiler with internal coal supply mechanism (Model example: Carborobot). Coal feeding to the boilers coal supply mechanism is done manually by bagful.

The timing of coal feeding to the furnace is unknown, but the combustion stabilizes better than other boiler types.

The sampling and measurement methods are the same as the case for “Section 4.5.2 Frequent Manual Coal Feeding”.

However, the time and weight of the additional, manual, coal feeding must be recorded in the filed notebook, if it occurs.

4.5.6 Boilers with Flue Gas Wet Scrubber Devices

A boiler with a flue gas wet scrubber device can reduce the concentration of dust and SO2. The following consideration is necessary for sampling.

a) Dust sampling filters may become wet due to the water vapor from the wet scrubber. A used filter may not be able to perform its filtering operation so that the suction speed will drop drastically and becomes incontrollable. If you suspect such incident, stop the sampling operation and replace the filter before resuming the sampling.

b) When the low concentration SO2 level cannot be measured, suspect that the process mechanism with chemical such as lime to absorb SO2 gas may be installed in the boiler. Verify for such mechanisms or chemicals.

4.6 Fan Operating Condition and its Effect to Sampling

As described under Section 3.2, there are three types of Boiler fans.

1. Forced Draft Fan
2. Induced Draft Fan
3. Balanced Fans (furnished with induced and forced draft fans)

Adjust the sample timing as paying attention to the following fan characteristics. However, continue the gas component measurements regardless of the fan operating condition (ON or OFF).

4.6.1 Timing of Coal Feeding

	Operational Characteristic	Sampling Consideration
1	The fan is turned OFF during coal feeding. The fan is turned back ON immediately after the feeding.	Stop dust and moisture sampling during coal feeding. Start dust and moisture sampling immediately after the fan is back ON.
2	The fan is ON regardless of the coal feeding and ash raking.	Continue dust and moisture sampling even during coal feeding.

An operation example is shown below.

< Operation Example for Balanced Draft Fans>

Stop both fans during coal feeding. After coal feeding is over, turn ON only the forced fan until the good combustion is observed, upon which time turn ON the induced fan then turn OFF the forced fan.

In this case, start dust and moisture sampling when the induced fan is turn ON. Continue the sampling even when the fan is switched to the induced fan.

<When one of the fans becomes inoperative while sampling>

Record the time when one of the fans became inoperative, and continue sampling. The flow rate will change, which alters the dust sampling suction condition. You must adjust the dust sampling control accordingly.

4.6.2 When a Fan Stops While Sampling

Many boilers adjust the hot water supply volume by stopping and restarting the hot water supply based on the temperature of the returned water and/or on the boiler pressure meter.

In such condition, the fan can be turned OFF when the hot water supply is stopped, at which time, the air draft becomes natural. This causes the furnace to starve for oxygen. The coal will also starve for oxygen, which causes the furnace temperature, flue gas speed and dust concentration to go down.

When a fan operation stops during sampling, read the flow rate from the device. If the reading is less than 2m/s, then stop the dust sampling and wait until the fan is turned back ON.

When the fan is turned back ON (for example within a few tens of minutes from the time it went OFF), restart the dust sampling. Stop the particular sampling if the total sampling time of a filter reaches 20 minutes. This concludes one sampling period. Replace the filter before restarting another period of sampling.

The fan’s ON/OFF times must be recorded in the field notebook since they are used later in calculating the concentration values.

4.7 Concerning Calculation Methods of Measured Values

Upon sample collection and data collection in the field, you return to your laboratory, calculate the representative values of the flue gas concentration based on the collected data. The representative values will be included in the reports later.

This section provides procedures and cautions to calculate and obtain representative concentration values from a set of individually collected data. The calculation can be done automatically by plugging the numbers in the calculation spreadsheet. Refer to the corresponding technical manual for the calculation details.

4.7.1 Gas Concentration Calculation

Each concentration value of gas components (NOx, SO2, CO, CO2 and O2) in the flue gas is continuously measured and recorded by a flue gas analyzer. Instantaneously measured data for each component is stored in a data logger once every 10 seconds (at the present setup).

As described under Section 4.5.1 “Basic Measurement Rules”, gas component measurements are continuously performed during the entire measurement periods including the dust and moisture sampling periods.

There are three basic processes to calculate representative values of gas concentration.

1) O2 Conversion

Using the O2 collected data, obtain the O2 converted concentration values for each gaseous pollutant data. The following figure shows an example of calculation sheet performing the O2 conversion.

Time	PG-250 raw data					PG-250 O2-based(9.33%)		
	NOX	SO2	CO	CO2	O2	NOX	SO2	CO
	ppm	ppm	ppm	%	%	ppm	ppm	ppm
12:20:00	97	354	55	7.486	12.3	131	478	74
12:20:10	98	357	55	7.526	12.3	131	479	73
12:20:20	98	359	55	7.558	12.3	131	480	73
12:20:30	98.5	362	55	7.576	12.2	131	482	73
12:20:40	98.5	363	55	7.576	12.2	131	484	73
12:20:50	98	365	55	7.576	12.2	130	487	73

Six raw data samples are taken every minute for each element (highlighted in yellow)

Of these elements, NOx, SO2 and CO are defined by MNX as harmful materials with regulated emission standards. Each sample data produces the concentration value highlighted in green when it is calculated in the following O2 conversion equation.

$$Ci^{*} = Ci \times \frac{21-9.33}{21-O_2 i} (\text{ppm})$$

where

Ci: i^{th} gas concentration (ppm)

O_2i: O2 Concentration raw data that coincides with

Example: NOx in the table above:

$$131 \fallingdotseq 97 \times \frac{21-9.33}{21-12.3}$$

Ci sample time (ppm) Ci * : i^{th} gas concentration (ppm) after O2 Conversion 9.33: Standard oxygen concentration (%) that corresponds to the excess air ratio 1.8 that is described in the HOB Emission Standard	

However, when the O2 Concentration is measured to be 20 % or more, you must correct and set the O2 value to be 20%, and then perform the O2 Conversion above.

2) Bad Data Removal

You might come across an incident that a normal measurement cannot be performed due to unrelated work you had to take care of or due to some problems you encounter while you are performing flue gas analyzer measurements. In such case, the data is abnormal and should be discarded. You must use only the normally or appropriately collected data for the calculation of the representative values.

See the following trouble examples.

① The sampling is completed with the first filter that is replaced with the 2^{nd} filter. However, the sampling tube of the flue gas analyzer came out by accident, which sucked the air into the analyzer.

② Flue gas was not suctioned in because the moisture was frozen in the trap immediately after the flue gas sampling probe. Thus, small leakage at connection point(s) in downstream tube from the sampling probe drew the air into the flue gas analyzer. The flue gas analyzer made the measurements under this condition.

3) Calculation of Representative Values (Average Calculation)

First, you must remove the bad data. Then the representative values to be reported are calculated by the following equation:

$$C = \frac{\Sigma Ci^*}{n}$$

Where

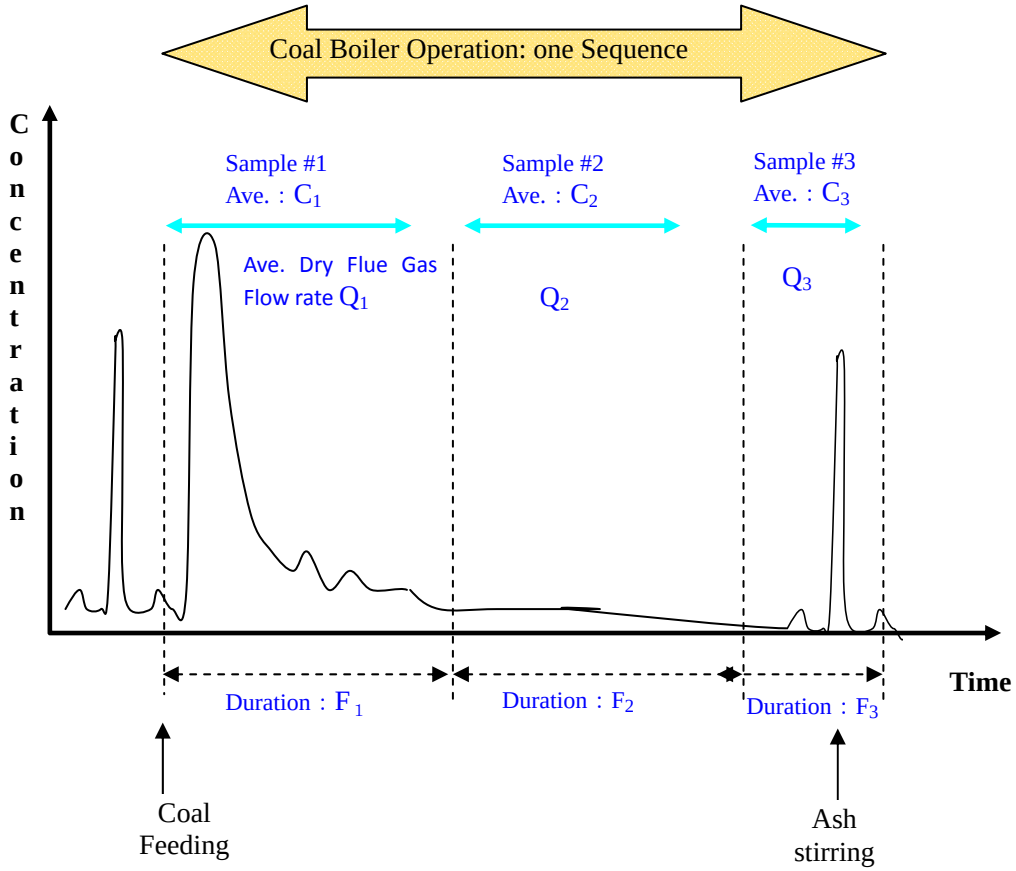
C : Gas Concentration Representative Value (ppm) of the monitored boiler

n : the number of Ci^* Data (after removing bad data)

Ci^*: Gas Concentration (ppm) of the i^{th} Sample after O2 Conversion

4.7.2 Dust Concentration Calculation

One data is collected for every ten (10) seconds for continuous measurements of gas components. Dust is collected over a certain period using a filter, therefore, one collection Sequence can be described as shown in the Figure below, which provides three (3) samples as an example.



Assume a case of three dust sample periods. The representative values of the dust concentration can be calculated by the following two processes.

a) Average Dust Concentration Calculation

This method calculates the time weighted average concentration value of a Sequence by including the time beyond (before or after) the actual sampling time of a Sequence.

$$\text{Average Dust Concentration } C' = \frac{C_1Q_1F_1 + C_2Q_2F_2 + C_3Q_3F_3}{Q_1F_1 + Q_2F_2 + Q_3F_3}$$

Where

C' : Dust time weighted average concentration value of the measured boiler (g/Nm^3) (prior to O2 conversion)

C_1 : Dust concentration of sample #1 (g/Nm^3)

Q_1 : Average flow rate of dry gas during Sample #1 (Nm^3/h)

F_1 : Assumed duration that holds the C_1 Average concentration (min)

（The symbols for Samples #2 & #3 will follow the same except the suffix)

The actual dust sampling lasted for the duration that is highlighted in light blue in the figure.

Take an example of Sample #1. This calculation assumes that an emission intensity of C1Q1 (g/h) lasted during the F1 (minutes) that was longer than the actual sample duration.

Take a case of a two-hour-collection Sequence, for example. Three filters are not sufficient to handle the entire samples for two hours. However, we can calculate an average concentration values that are much closer to the true value.

b) Calculation of Representative Value (O2 Conversion)

The representative value of dust concentration to be reported is calculated by O2 converting the time weighted concentration average value.

$$C = C' \times \frac{21-9.33}{21-O_{av}}$$

Where

C: Representative value (g/Nm^3) of the dust concentration from the measured boiler (upon the O2 conversion)

C´: Dust time weighted average concentration value of the measured boiler (g/Nm^3) （prior to O2 conversion）

O_{av}: Average O2 Concentration (ppm)

9.33: Standard Oxygen Concentration (%) corresponding to the air excess ratio of 1.8 that is listed in the HOB Emission Standard

4.7.3 Calculation of Emission Factor

For each monitored boiler, the emission factor (EF) can be calculated in the following manner for each pollutant that is specified in the MNS emission standard:

$$EF = \frac{CQ}{S}$$

where

EF: Emission Factor (kg/t). Pollutants weight during one ton of coal combustion

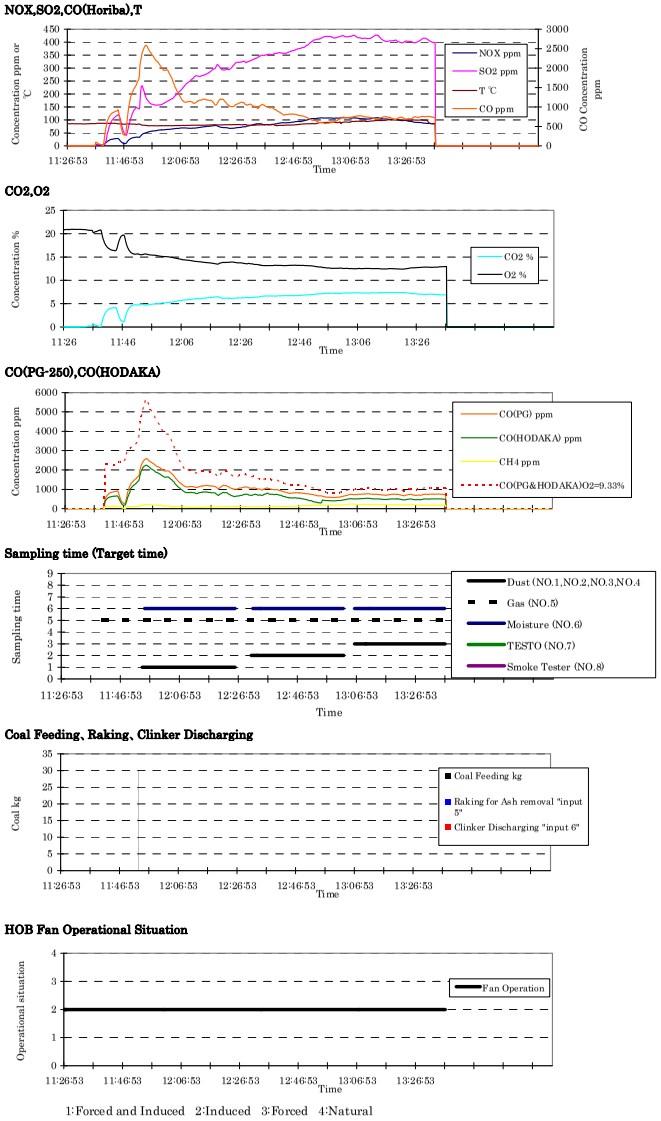
C: Representative value of the pollutant concentration (g/Nm^3)

Q: Average value of the flue gas flow rate (Nm^3/h)

S: Supplied weight of coal (kg/h)

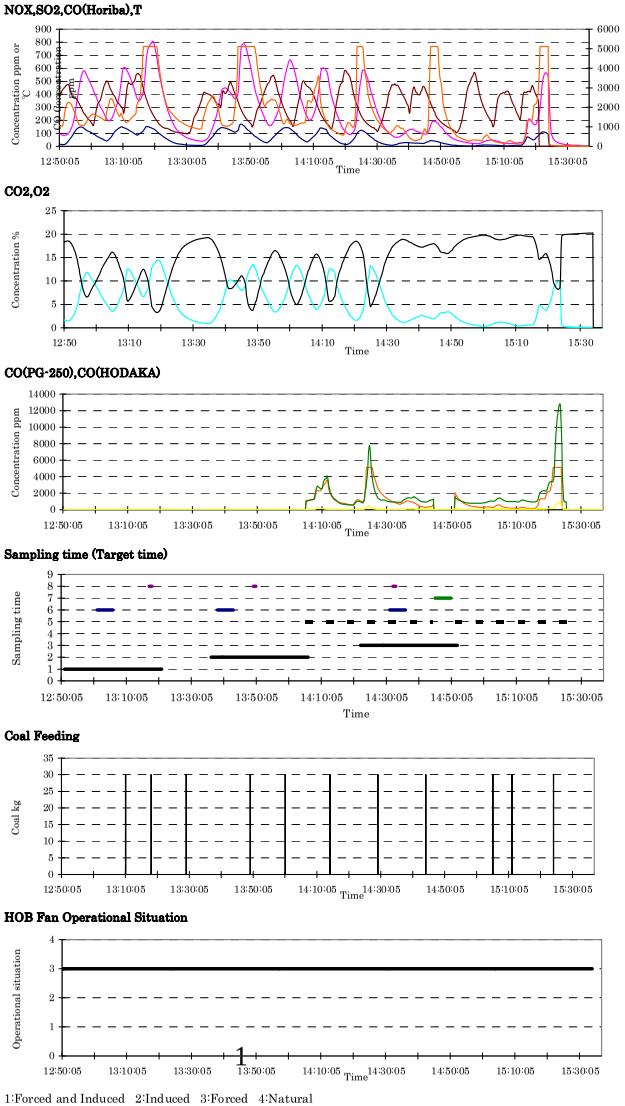
Appendix 1

HOB Example 1　A Simple Pattern
Coal fed only once;
Fan always ON



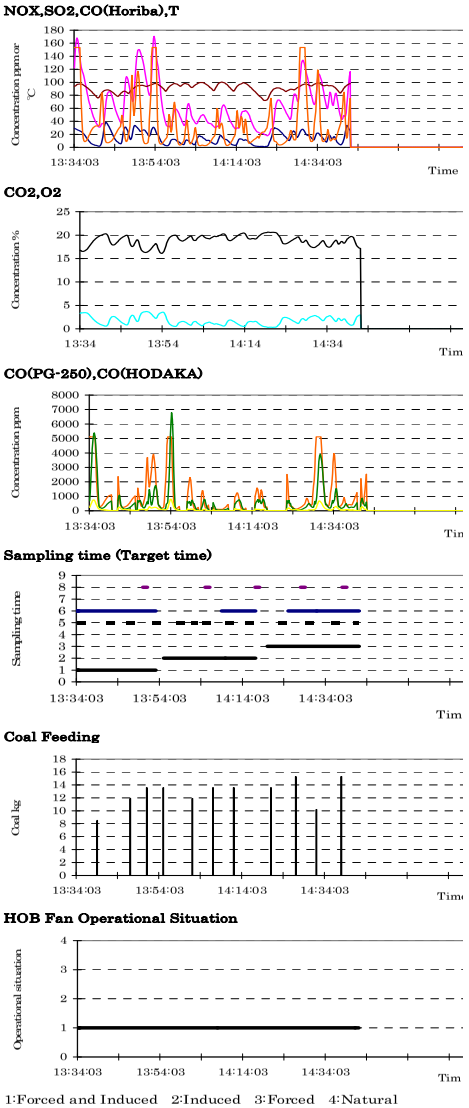
1:Forced and Induced　2:Induced　3:Forced　4:Natural

HOB Example 2
Coal fed every 10 min, approx.; Fan always ON



1:Forced and Induced　2:Induced　3:Forced　4:Natural

HOB Example 3
Coal fed every 5 to 10 min, approx.
Fan always ON

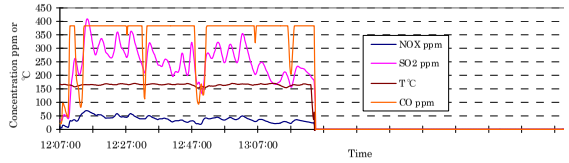


1:Forced and Induced　2:Induced　3:Forced　4:Natural

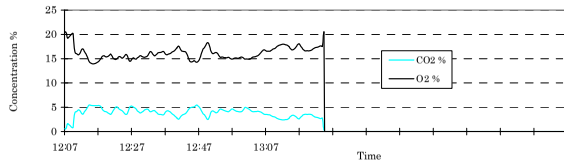
Appendix 1

HOB Example 4
Continuous Feeding;
Fan always ON

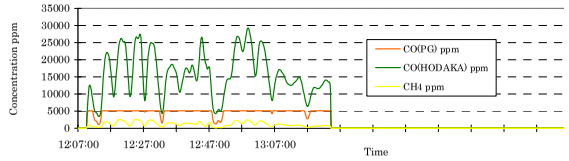
NOX,SO2,CO(Horiba),T



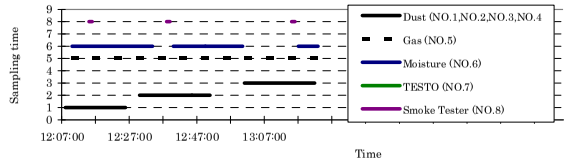
CO2,O2



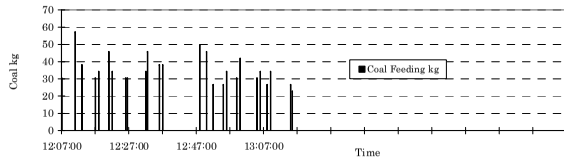
CO(PG-250),CO(HODAKA)



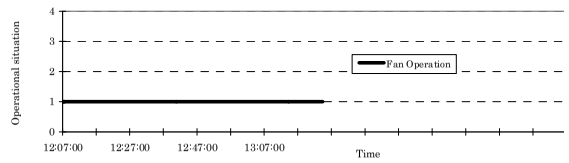
Sampling time (Target time)



Coal Feeding



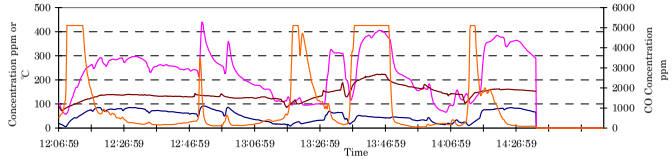
HOB Fan Operational Situation



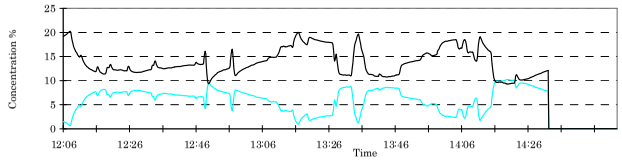
1:Forced and Induced 2:Induced 3:Forced 4:Natural

HOB Example 5
Feeding as Needed;
Natural air draft

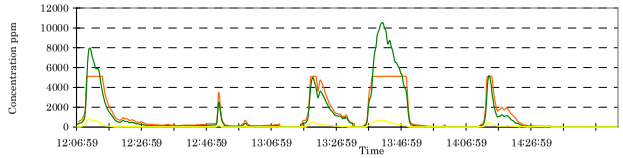
NOX,SO2,CO(Horiba),T



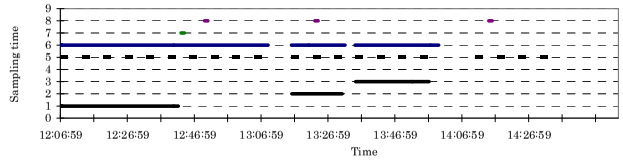
CO2,O2



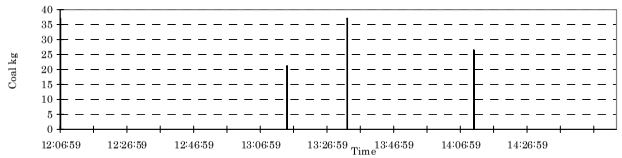
CO(PG-250),CO(HODAKA)



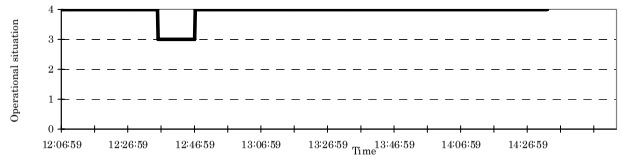
Sampling time (Target time)



Coal Feeding



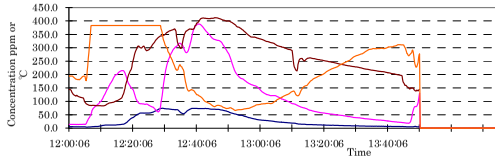
HOB Fan Operational Situation



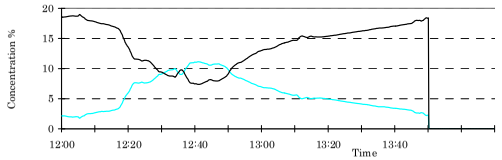
1:Forced and Induced 2:Induced 3:Forced 4:Natural

Example 6 Ger Stove
Coal fed only once;
Natural air draft

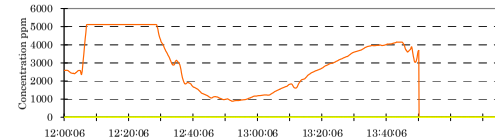
NOX,SO2,CO(Horiba),T



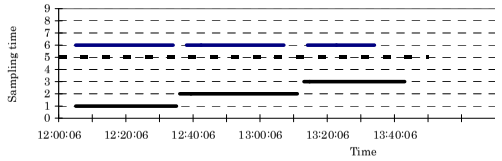
CO2,O2



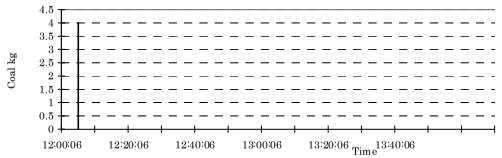
CO(PG-250),CO(HODAKA)



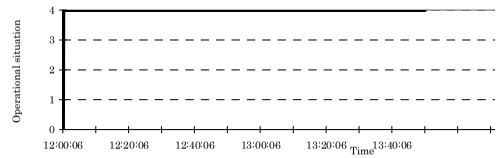
Sampling time (Target time)



Coal Feeding



HOB Fan Operational Situation

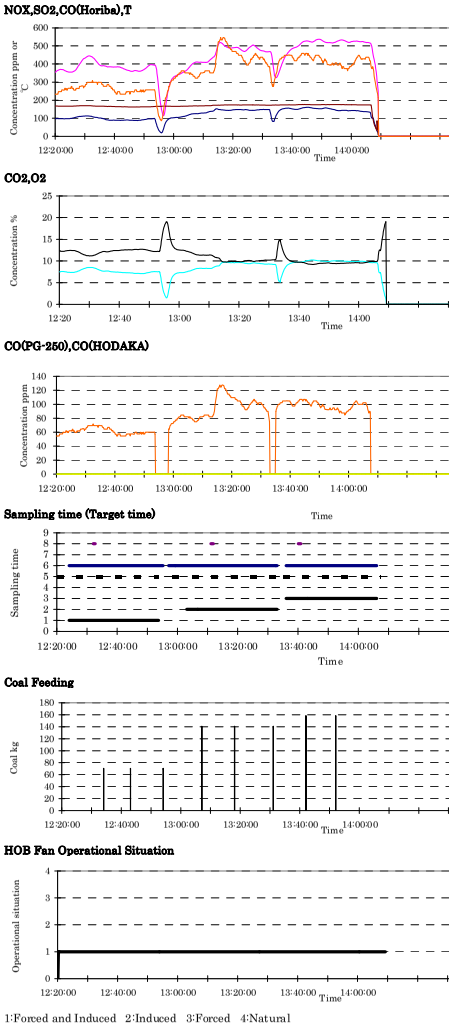


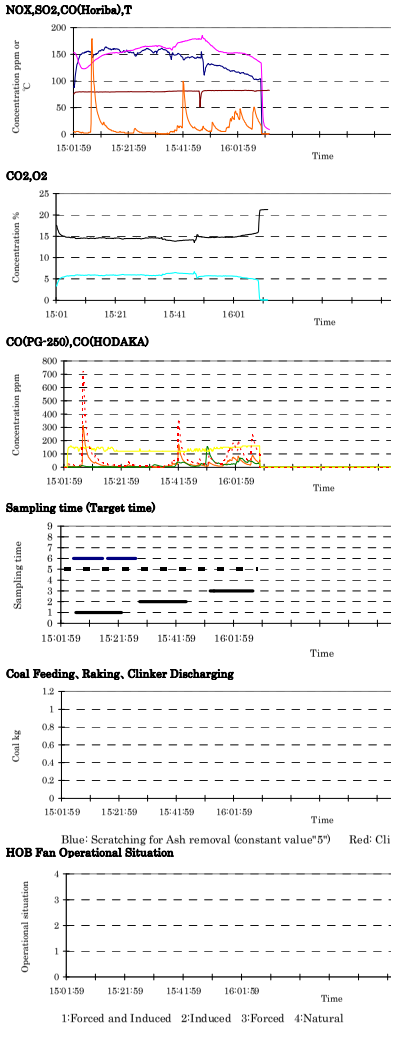
1:Forced and Induced 2:Induced 3:Forced 4:Natural

Appendix 1

HOB Example 7 Large Boiler Stable Combustion; coal fed every 10 min. approx.

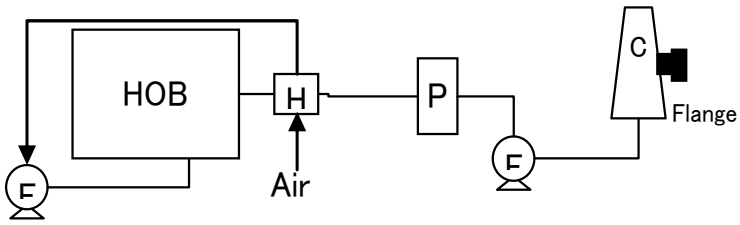
Thermal Power Plant
Stable Combustion





Appendix 2 HOB Basic Information

The monitoring sample timing is determined for every boiler by taking the operational circumstance of the day into account. Thus, it is essential to record the following items by obtaining the boiler information from the boiler operator before the sample collection.

NO.	1
HOB Type	○○○○
Photos	 HOB  Chimney
System Diagram per each Chimney	 F: Fan P: Purifying Facility C: Chimny H: Heat Exchager

		Contents (Example)	Notes
Basic Information	Installation Location	xxxx	
	Date of Visit	January 20, 2012	
	Temperature of Visit (°C)	Ave. -23 (min -31, max -13)	
Boiler Type	Maximum Output Capacity (MW)	--	
	Installation Date	--	
	Number of Boilers	1	
	Air Circulation Type	Balanced	
	Coal Feeding Method	Manual	
	Location of the Sensor Access	Chimney	
	Dust Collector Type	Cyclone	
	Sulfur Removal Device Type	None	
Operating Conditions	Supply Water Temp. Setting (°C)	80	
	Fan Operating Method	Random, intermittent	
	Fan ON/OFF Timing	ON at 80°C; OFF at 70°C	
	Smoke Leak	A little just before chimney	
	Damper Use	Unconfirmed	Damper exists
	Clinker Removal Method	Pushed out to the clinker receiving tray at the end of HOB	
	Frequency of Clinker Removal	Once before every	

		feeding	
	Frequency of Ash Raking	A few times per hour	
	Maintenance of Dust Collector	Once every one half day	
Fuel Related Items	Coal Type	Nalaikh	
	Coal Size	Crushed coal	A few cm size
	Feeding Tool (e.g. Shovel)	Shovel	
	Coal Feeding Interval	Every 20 min, approx. (10 scoops per feeding)	
	Total Coal Weight during Visit (kg/h)	228	
	Total Coal Weight during the most severe winter (kg/h)	270	
	Other material fed	Paper waste once in a while	
Hot Water Demand	Demand Source	Schools, hospitals, residence in vicinity	
	Demand Time Span	24 hrs/7days (no stoppage)	
Observed or communicated matters	- Coal thickness over the grate is manually controlled to 8 to 12 cm. - Spare HOB is operated only during the cold seasons. - Coal is distributed to multiple HOBs at different times. - Operator adjusts the coal feeding timing depending on the ash characteristics.		

Appendix 3 Facility Information Record

Record the following facility information on the day before the measurements.

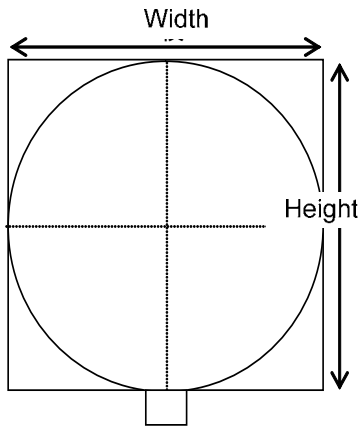
Monitoring Items: Dust, Nox, Sox, CO, Stack Gas Volume, Others ( )

Measured Location	Facility Name			
	Address			
	Phone: Section: Person in Charge			
Measured Date	Yr Mon Day		Time	: ~ :
Weather			Pressure	(kPa)
Temperature (indoor / Outdoor)	℃/ ℃		Outdoor Moisture	(%)

■ Volume of Fed Coal

Coal Type	1) Nalaikh 2) Baganuur 3) Shiveeovoo 4)Other ( )						
Feeder	1) Shovel 2) Bucket 3) Others ( )						
Coal Weight for each feeding	1st	2nd	3rd	4th	5th	Average	(kg)
Coal Weight per Hour	(kg/h)						

■ Positions of Measured Points

Location	1) Chimney 2) Smoke Stack						
Measurement Position Cross Section							
							
	Duct Shape	☐ Circular					
		☐ Rectangular					
	Flange Length	mm					
	Internal Diameter	mm					
	Radius (R)	mm					
	Width (2R)	mm					
	Height	mm					
* Mark the position of the measurement location in the diagram above.							

Measurement Position	Distance from the edge of the flange	Position	Distance from the edge of the flange
①	mm	⑦	mm
②	mm	⑧	mm
③	mm	⑨	mm
④	mm	⑩	mm
⑤	mm	⑪	mm
⑥	mm	⑫	mm

Notes: (System, Fan position, air circulation method, etc)

Measurement Position Area of Cross-Section	Circular Duct: Radius (	m) ^ 2 x 3.14 =	m^2
	Circular Duct: Radius (	m) ^ 2 x 3.14 =	m^2

Appendix 4 Pre-Sampling Measurement Record / Dust Sample Record (Excel Sheets)

In order to use manual dust samplers, measurements are necessary on temperature, pressure and moisture of the flue gas prior to the actual dust sampling (Pre-sampling Measurements). This data sheet is used also for the calculation of the isokinetic sampling speed and for the recording of the dust sampling conditions.

Урсгал хурдны хэмжилт • Тоос соруулах хурдыг тохируулах тооцоо

Утга оруулах
Томъёо
Ур дүн
Өөрчлөхгүй

Агаарын даралт

Агаарын даралт	kPa	89	89	89	

Чийгний хэмжээ…Зуухны галлагааныаас хамаарч чийгний хэмжээг тодорхойлох

Агүүлгэ	Нэгж	1-1	1-2	2-1	2-2	3-1	3-2	Дундаж
Хэмжилт эхэлсэн цаг		10:20		10:32		10:44		
Хэмжилт дууссан цаг		10:30		10:42		10:54		
Метрийн эхний заалт	L	2426.9		2436.98		2446.98		
Метрийн сүүлийн заалт	L	2436.98		2446.98		2458.7		
Соруулах хэмжээ	L	10.08		10		11.72		
Метрийн хэм	℃	-4.8		-7.7		-9.5		-7.3
Метрийн даралт	kPa	0.02		0.02		0.02		0.02
Ханасан уурын даралт	kPa	0		0		0		
Чийг баригчийн эхний жин	g	119.45	118.58	122.5	124.63	118.17	116.05	
Чийг баригчийн сүүлийн жи	g	119.46	118.86	122.49	124.88	118.16	116.45	
Чийгний хэмжээ	g	0.01	0.28	-0.01	0.25	-0.01	0.4	
		0.29		0.24		0.39		
Чийгшил	%	3.85		3.20		4.35		3.80

Нөхцөл байдал

Утааны хийн нягт（Хэвийн байдал）…Тестоогоор хэмжсэн ур дүнг оруулах

Агүүлгэ	Нэгж	1 дэхь	2 дахь	3 дахь	4 дэхь	5 дахь	6 дахь	7 дахь	8 дахь	9 дахь	10 дахь	Дундаж
Хэмжилтийн хугацаа		10:30	10:38	10:50	10:58							
CO2	%	1.35	1.84	2.51	1.83							1.88
O2	%	20.14	18.61	18.79	19.74							19.3
CO	%	0.02	0.02	0.04	0.05							0.033
NOX	%	78.49	79.53	78.66	78.38							78.8
Чийг	%											3.80
Агаарын харьцаа												12.74
Хэвийн нөхцөл дахь нягт	kg/m3											1.279

Статик даралт **Температурыг оруулах**

Агүүлгэ	Нэгж	1	2	3	4	5	6	7	8	Дундаж
Шингэний нягт	℃	-13								
	g/cm^3	0.734	0.734	0.734	0.734	0.734	0.734	0.734	0.734	
Налуу		1	1	1	1	1	1	1	1	
Манометрийн 0 цэг	Pa	0	0	0	0	0	0	0	0	
Манометрийн заалт	Pa	-230								
Манометрийн заалтын зөрү	Pa	-230	0	0	0	0	0	0	0	
Статик даралт	kPa	-1.657								-1.657

※Статик даралтыг сонгох

----------Үргэлжилсэн хэмжилт----------

Утааны хийн нягт（Утааны те :

Агүүлгэ	Нэгж	0 мин	1 мин	2 мин	3 мин	4 мин	5 мин	6 мин	7 мин	8 мин	9 мин	10 мин	11 мин
Хэвийн нөхцөл дахь нягт	kg/m3	1.279	1.279	1.279	1.279	1.279	1.279	1.279	1.279	1.279	1.279	1.279	1.279
Утааны темп	℃	209		192		196		198		192		191.5	
Агаарын даралт	kPa	89	89	89	89	89	89	89	89	89	89	89	89
Статик даралт	kPa	-1.657	-1.657	-1.657	-1.657	-1.657	-1.657	-1.657	-1.657	-1.657	-1.657	-1.657	-1.657
Утааны хийн нягт	kg/m3	0.625		0.647		0.642		0.639		0.647		0.648	

Динамик даралт（Микроманометрийн утгыг оруулах）

Агүүлгэ	Нэгж	0 мин	1 мин	2 мин	3 мин	4 мин	5 мин	6 мин	7 мин	8 мин	9 мин	10 мин	11 мин
Хэмжилт эхэлсэн цаг													
Шингэний нягт	℃	-6											
	g/cm3	0.730	0.730	0.730	0.730	0.730	0.730	0.730	0.730	0.730	0.730	0.730	0.730
Налуу		5	5	5	5	5	5	5	5	5	5	5	5
Манометрийн 0 цэг	Pa	2	2	2	2	2	2	2	2	2	2	2	2
Манометрийн заалт	Pa	70		78		77		68		70		70	
Манометрийн заалтын зөрү	Pa	68	-2	76	-2	75	-2	66	-2	68	-2	68	-2
Хоншууны диаметр	mm	8	8	8	8	8	8	8	8	8	8	8	8
Хийн урсгал хурд	m/s	4.79		4.97		4.96		4.67		4.71		4.70	
Чийгний хэмжээ	%	3.80	3.80	3.80	3.80	3.80	3.80	3.80	3.80	3.80	3.80	3.80	3.80
Метрийн темп	℃	-8		-8		-7		-7		-7		-7	
Утааны темп	℃	209	0	192	0	196	0	198	0	192	0	191.5	0
Агаарын даралт	kPa	89	89	89	89	89	89	89	89	89	89	89	89
Статик даралт	kPa	-1.657	-1.657	-1.657	-1.657	-1.657	-1.657	-1.657	-1.657	-1.657	-1.657	-1.657	-1.657
Метрийн даралт	kPa	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Ханасан уурын даралт	kPa	0	0	0	0	0	0	0	0	0	0	0	0
Соруулах хэмжээ	L/min	7.49		8.07		8.00		7.50		7.66		7.66	
Соруулах хурд	sec/L	8.01		7.44		7.50		8.00		7.83		7.83	

Тоосны агууламж

Агүүлгэ	Нэгж	1	2	3	4
Метрийн эхний заалт	L			25311	
Метрийн сүүлийн заалт	L			25634	
Соруулах хэмжээ	L			323	
Метрийн темп	℃			-8	
Метрийн даралт	kPa			0.03	
Ханасан уурын даралт	kPa	0	0	0	0
Агаарын даралт	kPa	89	89	89	89
Хуурай хийн хэмжээ	m3	#VALUE!	#VALUE!	0.2924	#VALUE!
Фильтрийн эхний жин	g			1.7662	
Фильтрийн сүүлийн жин	g			1.9252	
Фильтрийн цэвэр жин	g	0	0	0.159	0
Тоосны агууламж	g/m3			0.5438	

Пидантийн хэлбэр	1	○:1, □:2	
Дундаж хурд	4.72	(m/s)	
Хөндлөн огтлол	0.064	(m^2)	
Утааны темп	199	(℃)	
Статик даралт	-1.657	(kPa)	
Чийгтэй утааны хэм	540	(m^3/h)	
Хуурай утааны хэм	520	(m^3/h)	

Дугуй хэлбэртэй яндан		Дөрвөнжин хэлбэрийн яндан	
Диаметр (mm)	285	z	500
Хөндлөн огтлол	0.06376163	өргөн (mm)	800
Фильтрийн урт(mm)	190	хөндлөн огтлол	0.4

Appendix 5 Record of Boiler Operations

Record daily operational parameters of boilers from the beginning of the measurements to the end (e.g. coal feeding timing, fan use, concentration of stack smoke), along with the events such as boiler and measurement troubles. Record them every minute if possible.

Date :
Site:
Target HOB:
Unit wight of fed coal (kg):
Ventilation system:

Recorder:

Time	Condition		Operation						Other
	Velocity of Flue gas (m/s)	Temperature of Flue gas (℃)	Number of fed coal by scoop or carry	Weight of fed coal (kg)	Raking of coal in a furnace (on:1 off:0)	Removing of clinker (on:1 off:0)	Working of Forced Draft Fan (on:1 off:0)	Working of Induced Draft Fan (on:1 off:0)	Remarks
:									
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Appendix 6 Automated Measurements Sampling Record

The Excel sheet (ref. Concentration Calculation Manual) automatically calculates the flue gas report values when the data is transferred from the logged data of a gas analyzer and from the measured data of an Automated Dust Sampler.

2 Sampling Hole Installation Procedure

Technical Guideline:

Sampling Hole Installation Procedure

for Stack Gas Measurement

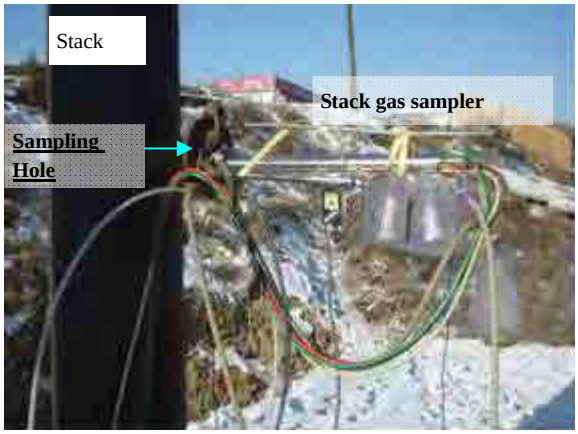
Air Quality Department of Capital City

Written by Gan-Ochir Davaajargal

In Mongolia, electricity and hot water for industry and civil life are supplied by power plants and smaller boilers.
Main reason of air pollution that is worsening in winter is estimated as these air pollutant sources. Measurement of air pollutant emission is one of the steps required for air pollution solution.

Generally, boiler emission gas is treated by air pollutant reduction equipment (i.e. dust collector), then emit via duct and then chimney (hereinafter referred as “flue”. Stack gas measurement is a process to analyze the stack gas sampled via a hole on flue.

This technical guideline illustrates the general requirements installing a new flue gas sampling hole on flue.



1. Requirement of flue section

Flue where new sampling hole is to be installed must meet with all the conditions below.

No.	Requirement of flue section
1	Thickness of flue wall on which new sampling hole is to be installed must be 1.5 mm or more. If flue wall is stained, the flue wall must be strong enough even if it is thicker than 1.5 mm.
2	Gas flow at the sampling hole installation point must not be blocked and must be smooth to emit the flue gas.
3	Flue wall material at the sampling hole installation point must be metal or building block.
4	Flue at the sampling hole installation point must be straight, and its sectional shape and effective area must not be changed. The straight length is recommended to be more than 7 times longer than its effective diameter, even though the project installed at less than this requirement on the flue that do not meet with this requirement.
5	Flue gas flow is recommended to be faster than 4 m/s at the sampling hole installation point, because it is recommended for gas flow measurement by Pitot-tube.
6	Sampling hole is better to be installed at vertical section of flue than horizontal section.

Requirement of installation point

Installation point of new sampling hole must meet with all the conditions below.

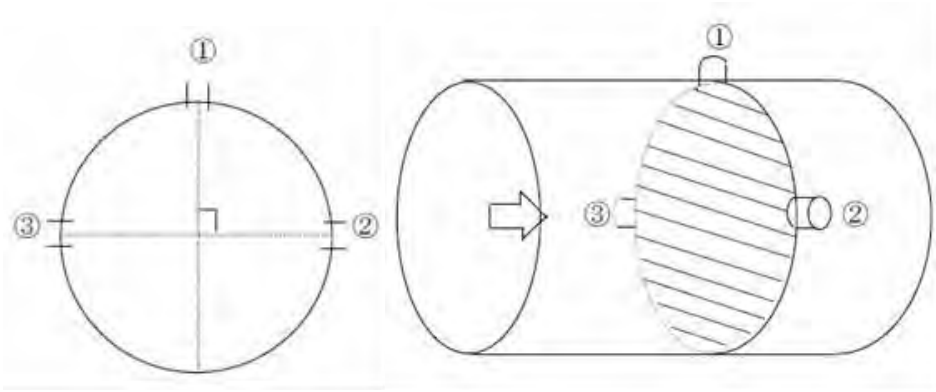
No.	Requirement of installation point
1	Flue gas flow at the installation point must not be air turbulence. The installation point should be selected where flue gas dust is expected to be evenly distributed by estimating the gas flow inside the flue. The installation point must far from any location which may cause turbulence (i.e. curve, blower and fan damper) as described below. Distance from any location which may cause turbulence Sampling hole must be installed more than 5 times of internal diameter downstream from any location which may cause turbulence, and same distance from the stack tail
2	Enough space for stack gas measurement work There must be a enough space for stack gas measurement work around the sampling hole installation point. The working space must be more than 2m width from sampling hole to the end of working space, which is required for flue gas sampling prove.
3	Sampling hole must located easily reachable by human Sampling hole should be located where stack gas measurement engineer can touch standing on ground or floor. Otherwise, it should be located where stack gas measurement engineer can touch standing on radar safely.
4	Safety for stack gas measurement engineer Sampling hole should be located where fall down risk of stack gas measurement engineer is low. It should also far from any machinery which may catch and damage stack gas measurement engineer. Floor for sampling work should be strong enough for the total weight and move of stack gas measurements engineers and equipment.
5	Additional conditions if sampling hole is not possible to be installed along vertical section, and is necessary to be installed along horizontal section Dust should not be deposited much at the installation point. Sampling hole should be located near to the end of horizontal section.

Location and count of sampling hole should be decided according to the characteristics of flue gas flow. Recommendation as follows is based on JIS Z8808, which is Japanese standard for stack gas sampling.

2.1 Location and count of sampling hole for circular section

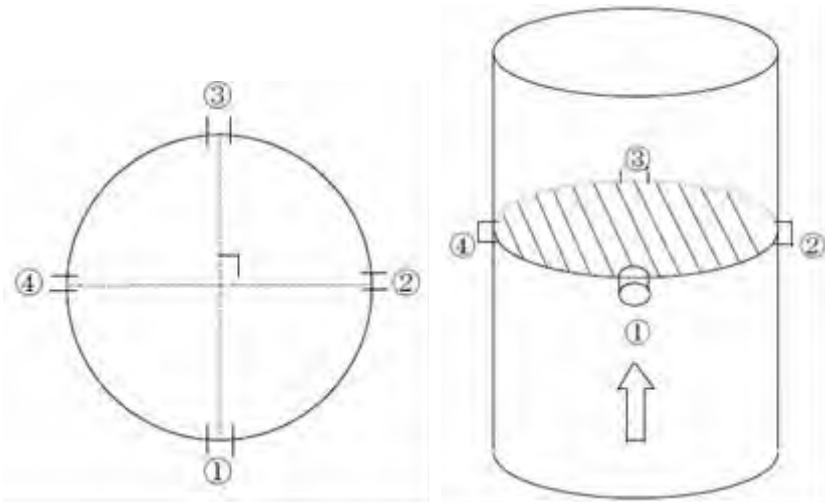
1） For circular horizontal section

This figure is for any flue of which circular section is larger than 0.25 m^2. One sampling hole is enough for any flue of which circular section is less than 0.25 m^2.



2） For circular vertical section

This figure is for any flue of which circular section is larger than 0.25 m^2. One sampling hole is enough for any flue of which circular section is less than 0.25 m^2.



2.2 Location and count of sampling hole for rectangular section

Count and location of sampling hole should be defined according to the process described below. The count of sampling hole should be increased according to the size of flue duct.

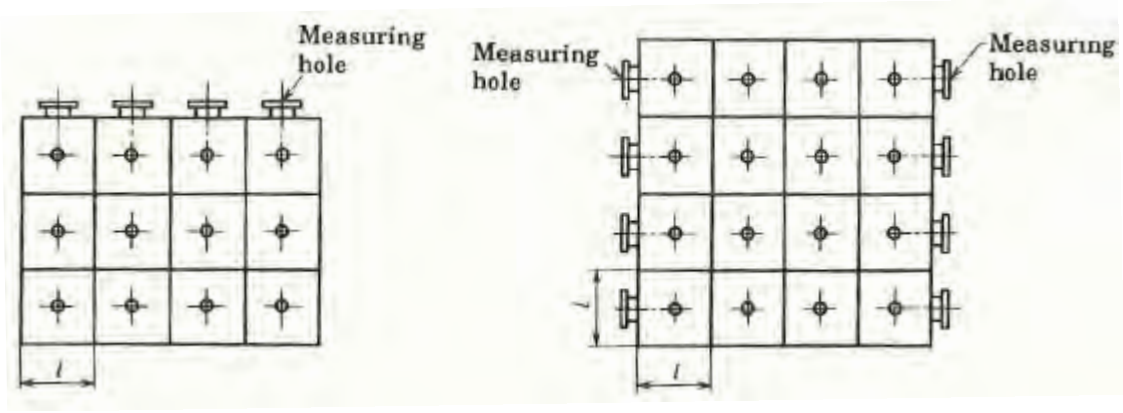
1) To calculate cross section area (A) by multiplying width and height

Width and height should be measured inside the flue duct. If it is not possible, it should be measured on its design plan instead.

2) Sampling hole and depth interval (ℓ) is calculated according to the rule here.

Area of cross section: "A" (m^2)	Sampling hole and depth interval: "ℓ" (m)
A≦1	ℓ≦0.5
1＜A≦4	ℓ≦0.667
4＜A	ℓ≦1

Following figures illustrate sampling hole and depth interval (ℓ). Flue duct cross section is divided into virtual rectangular of which dimension is "sampling hole and depth interval (ℓ)". Centroid points of each virtual rectangular is sampling points.



Virtual rectangular should be defined with "sampling hole and depth interval (ℓ)" and following rules.

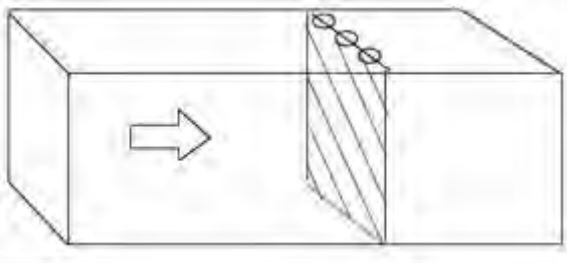
1) One side length of equal-size virtual rectangular, which is "sampling hole and depth interval (ℓ)", should be the maximum value which meets with the conditions shown in the table above.

2) The other side length should be the maximum value which meets with the conditions shown in the table above.

3) One sampling hole is enough for any flue duct of which circular section is less than 0.25 m^2.

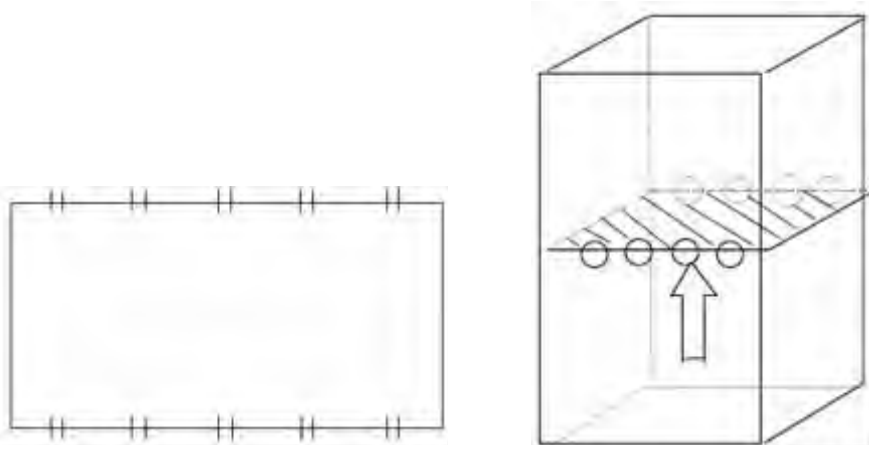
3) For rectangular horizontal section

Sampling hole should be installed on the upper side of flue duct, on one cross section and in equal distances.



4) For rectangular vertical section

Sampling holes on opposite sides will make measurement efficient if the side length of flue duct is larger than 2m approximately.

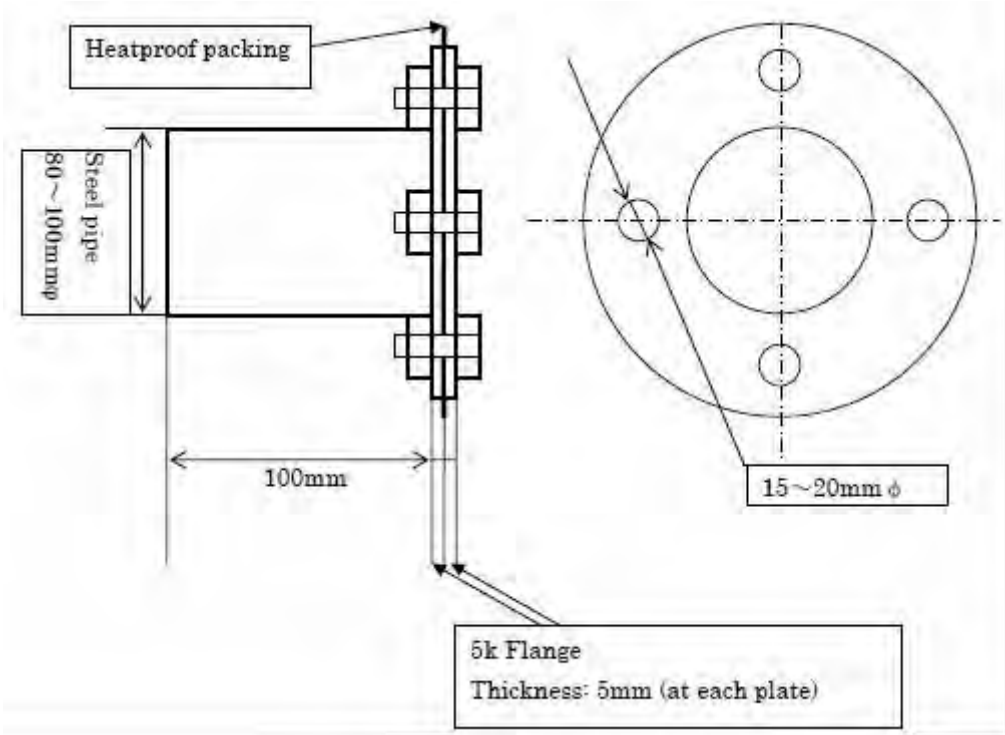


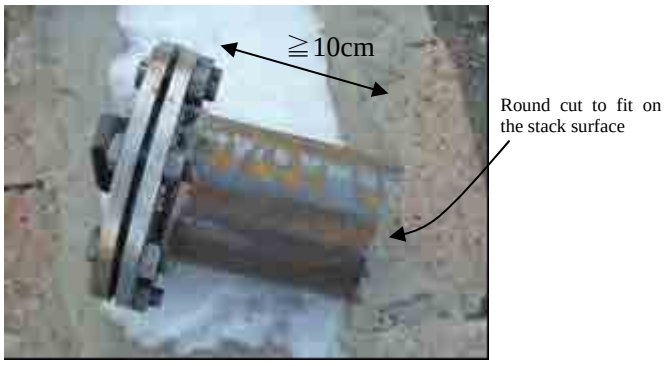
3. Sampling hole equipment design

Requirement of the sampling hole is as follows;

Length of the sampling hole pipe is 10cm or more. The pipe edge which will be installed on flue (left side of the figure below) should be cut to fit the flue shape, especially for the circular flue (as shown in the photo below) Heatproof packing seals air leak between flange and cover. Screw diameter is large enough since it is easy to be smaller by stain.

Sample design is shown below.





4. Welding

No.	Key issues on welding
1	For cast iron flue, sampling hole must be made of iron and installed by electric welding. For stainless steel flue, sampling hole must be made of stainless steel and installed by argon welding (Different materials should not be welded because it will be local electric cell at the welding point and cause corrosion.)
2	For brick flue, hole must be created by circular cutter for brick, and sampling hole must be installed with cement.
3	Any gap should not be found between the flue and sampling hole.
4	Rust inhibitor must be sprayed on all the screw portion of the bolts and nuts.
5	The welding worker must be qualified with license(s) required.

Opening a hole (using arc cutter for cast iron flue)


Checking if the opening fits with sampling hole equipment

Welding sampling hole equipment (using arc welding for cast iron flue)

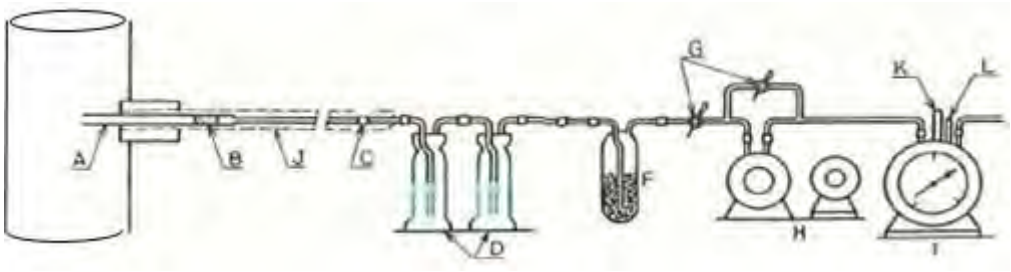

3 Procedure of Wet Sampling and Analysis of Stack Gas

SOx Analysis for Stack Monitoring

Measurement method; Precipitation Titrimetry (Arsenazo Ⅲ)

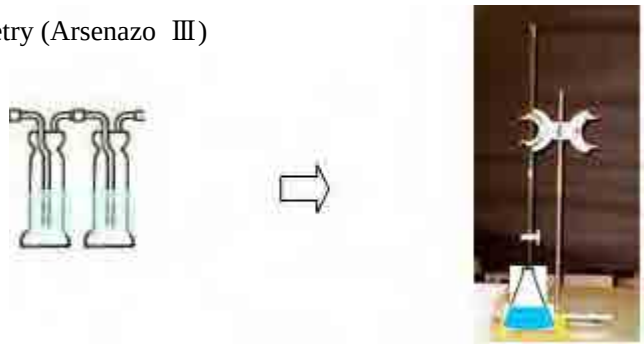
1. Outline of H_2S gas Analysis for Stack Monitoring

1.1 Gas Sampling



1.2 Analysis method

Precipitation Titrimetry (Arsenazo Ⅲ)

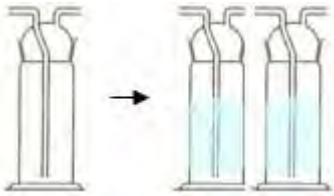


2. Preparation

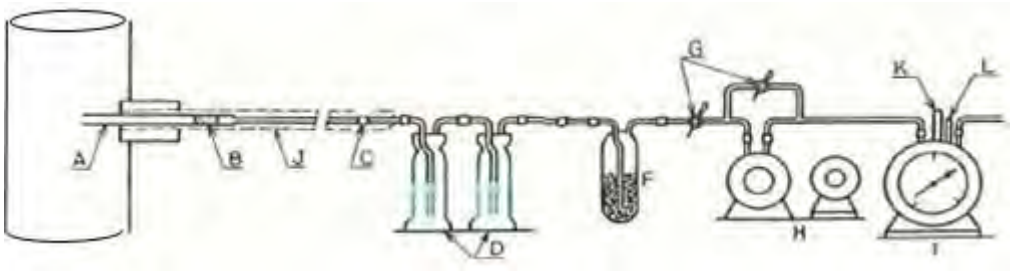
2.1 Absorbing Solution

Reagent
1. H_2O_2 (Hydrogen Peroxide) 30% 30ml
2. Deionized water 270ml

Put respectively 50 ml **Absorbing solution** into 250 ml impingers. Prepare 2 bottles.



3. Gas Sample Collection at Site (Stack)



Leak check test must be done before starting of gas sampling

Gas Sampling Flow rate: around**1** l/min

Total sampling gas volume: around **20** litters

SOx Analysis for Stack Monitoring

Measurement method; Precipitation Titrimetry (Arsenazo Ⅲ)

4. Analysis by Titrimetry

4.1 Preparation

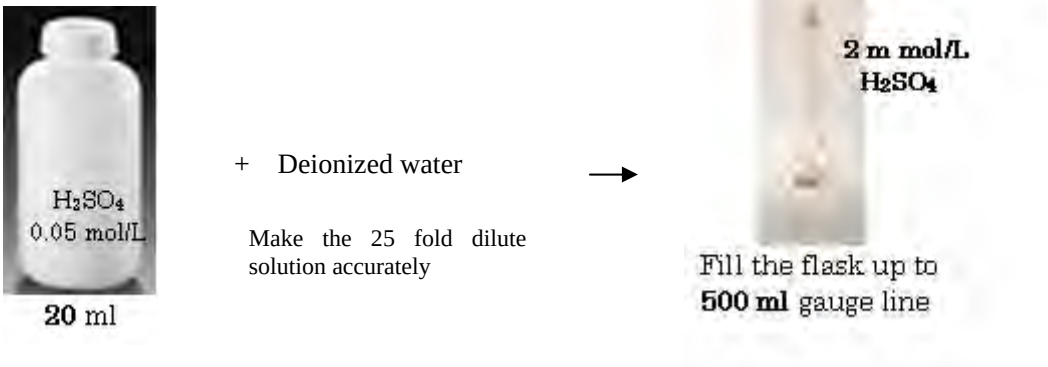
Reagent

1. Deionized water
2. H_2SO_4 0.05 mol/L (Sulfuric acid) 500ml bottle
3. Arsenazo Ⅲ
4. $Ba(OCOCH_3)_2$ (Barium acetate) 500g bottle
5. $Pb(OCOCH_3)_2 \cdot 3H_2O$ (Lead acetate trihydrate) 500g bottle
6. CH_3COOH (Acetic acid) 500ml bottle
7. 2-propanol 500ml bottle
8. C_2H_5OH (Ethanol 95) 500ml bottle

------ Reagent for determine the concentration factor of H_2SO_4 0.05 mol/L ------

9. Bromophenol blue
10. $NaCO_3$ (Sodium carbonate / anhydrous)

4.1.1 Preparation of 2 mmol/L H_2SO_4



It is required to determine the accurate concentration of the original solution ”0.05 mol/L H_2SO_4”, and express the concentration accuracy by “Factor number” before use it to make the diluted solution ”2 mmol/L H_2SO_4”. Many commercial products of it are provided with the factor number. If you intend to make this solution by yourself, reagents below are generally used for determination of the factor number.

1) Bromophenol blue 2) $NaCO_3$ (Sodium carbonate / anhydrous)

JIS K0103 provides the determination procedure of factor number.

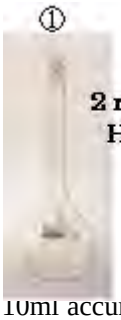
4.1.2 Preparation of Arsenazo Ⅲ Solution

Take 0.2 g Arsenazo Ⅲ reagent by mass measurement, and put into a beaker together with Deionized water 100ml. After shaking and filtration well of it, put this solution into the blown bottle as stock solution. It can use utmost one month in cold and dark storage.

4.1.3 Preparation of 5 m mol/L Barium Acetate Solution

The concentration of prepared "Barium acetate" must be determined by the titration procedure shown below.

--------- Put ①～④ solutions in 200ml Flask shown below--------



Take 10ml accurately by a Pipette

40 ml

③ CH_3COOH 1ml

④ Arsenazo Ⅲ Solution 4 or 6 drops

200 ml flask

Determine the concentration of B solution(Barium Acetate) by Titration method.
Use 5ml Micro bullet.
Solution color will be turned to blue after reaching to the endpoint where blue color will be stable more than one minute.
Readout the bullet scale to find the using volume of B.
Find the F number according to the formula below.

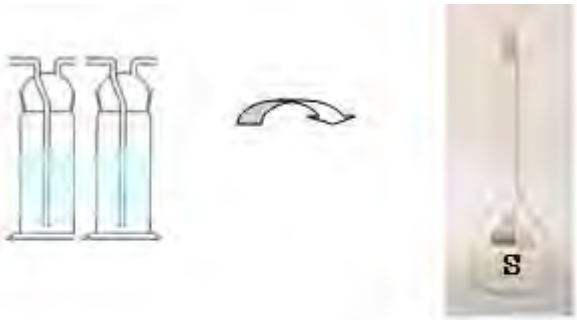
$$F = \frac{10 \times f}{a} \times \frac{2}{5}$$

Where;
F ; Factor of 5 mmol/L Barium Acetate
f ; Factor of 2 mmol/L H_2SO_4
a ; Total used volume of B solution by titration (ml)

4.2 Determination of the Sample Concentration

4.2.1 Sample Conditioning

Transfer the sampled liquid in two impingers into 250ml volumetric flask. Using little amount of ion exchanged water, rinse each impinger twice, and transfer all remained sample liquid into 250ml volumetric flask.



Fill the flask up to 250 ml gauge line with deionized water

------ Put ①~④ solutions in 200ml Flask shown below ----------

①

Sample **10**ml

②

40 ml

③ CH_3COOH 1ml

④ Arsenazo Ⅲ Solution 4 or 6 drops

200 ml flask

----------Sample is titrated by Barium Acetate Solution (B). ----------

Using the prepared 'Barium Acetate solution (B)' as titrant, make titration to determine the SOx concentration in Sample solution. Solution color will be turned to blue after reaching to the endpoint where blue color will be stable more than one minute.

Readout the bullet scale to find the using volume of B, and record it as '**a**' value (ml).

SOx Analysis for Stack Monitoring

Measurement method; Precipitation Titrimetry (Arsenazo Ⅲ)

----------Blank is titrated by Barium Acetate Solution (B). ----------

Using the prepared 'Barium Acetate solution (B)' as titrant, make titration to determine the SOx concentration which is possibly contained as unpurified matter in blank (absorbing) solution.

Put the absorbing solution 100ml into 250 ml flask and dilute with deionized water.

Fill the flask up to 250 ml gauge line with deionized water

------- Put ①～④ solutions in 200ml Flask shown below ----------

①

Blank **10**ml

②

40 ml

③ CH_3COOH 1ml

④ Arsenazo Ⅲ Solution 4 or 6 drops

200 ml flask

Using the prepared 'Barium Acetate solution (B)' as titrant, make titration to determine the SOx concentration in Sample solution. Solution color will be turned to blue after reaching to the endpoint where blue color will be kept stable more than one minute.

Readout the bullet scale to find the using volume of B, and record it as '**b**' value (ml).

Special care is required for discharging this waste solution, because it includes Lead and Arsenic as component.

5. SOx Concentration Calculation in Sample Gas

Calculate the volumetric concentration (volppm) of SOx in sample gas according to the formula shown below.

$$Cv = \frac{0.112 \times (a - b) \times F \times 250 / 10}{Vs} \times 1000 \quad (\text{volppm})$$

Assuming SO2 is only one component of SOx, concentration expressed by gravimetric unit is calculated by following formula.

$$Cw = \frac{0.320 \times (a - b) \times F \times 250 / 10}{Vs} \times 1000 \quad (\text{mg/m}^3{}_N)$$

Where;

Cv; volumetric concentration of sulfur oxides in Sample Gas (volppm)

Cw; mass concentration of sulfur oxides in sample gas when it is converted into sulfur dioxide SO2 ($mg/m^3{}_N$)

a; quantity of 5 mmol/L Barium Acetate solution consumed in sample titration (ml)

b; quantity of 5 mmol/L Barium Acetate solution consumed in blank titration (ml)

F; calculated factor of 5 mmol/L Barium Acetate solution

Vs; quantity of sample gas at standard condition (L_N)

0.112; gas volume of sulfur oxides (SO2 +SO3) at standard condition equivalent to 1ml of 5 mmol/L Barium Acetate solution (ml)

0.320; mass of sulfur dioxide (SO2) equivalent to 1 ml of 5 mmol/L Barium Acetate solution (mg)

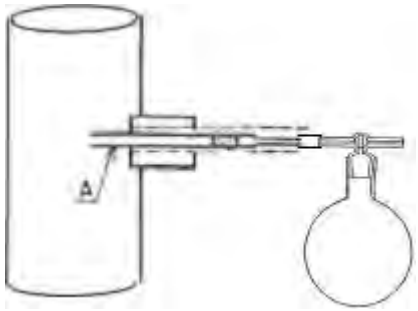
NOx Analysis for Stack Monitoring

Measurement method; NEDA (Naphthyl ethylenediamine absorptiometry) by Absorption Spectrometer

1. Outline of NOx gas Analysis for Stack Monitoring

1.1 Gas Sampling

The sample gas shall be taken using evacuated sampling flask.



1.2 Analysis Method

NEDA (Naphthyl ethylenediamine absorptiometry) by Absorption Spectrometer

Concentration of nitrogen oxides in flue gas are measured by the spectrophotometer.

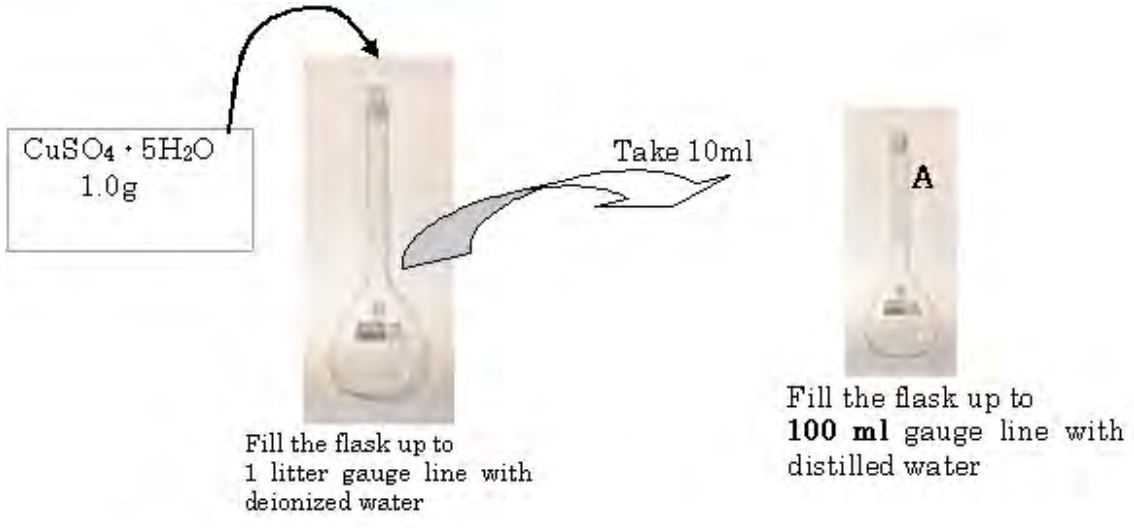
2. Preparation

2.1 Absorbing Solution

Prepare the two kind of absorbing solutions, A and B, to capture the nitrogen oxides in flue gas.

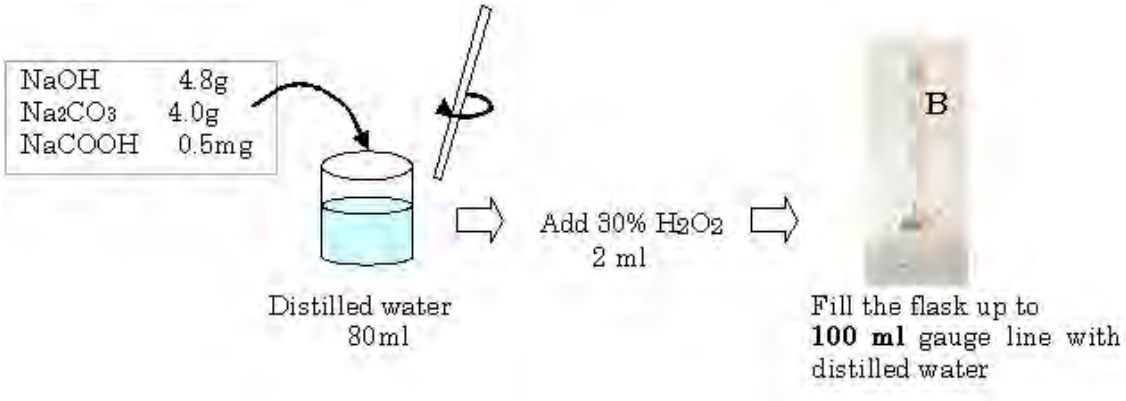
Reagent		
1. $CuSO_4 \cdot 5H_2O$	(Cupper Sulfate Pentahydrate)	500g bottle
2. NaOH	(Sodium Hydroxide)	500g bottle
3. Na_2CO_3	(Sodium Carbonate)	500g bottle
4. NaCOOH	(Sodium Formate)	500g bottle

< A solution >



Measurement method; NEDA (Naphthyl ethylenediamine absorptiometry) by Absorption Spectrometer

< B solution >



2.2 Sufanilamide HCl Solution

Dissolve 1.0 g sulfanilamide in 50 ml distilled water using 200 ml measuring flask. After adding 112 ml hydrochloric acid, fill the flask up to the gauge line with distilled water.

2.3 Naphthylethylenediamine Solution

Dissolve 0.1 g N-1- naphthylethylenediamine dihydrochloride in 100 ml distilled water.

2.4 NO_2^- Standard Solution (100mg NO_2^-/L)

Put 10 ml of "1000 mg NO_2^-/L standard solution (500 ml bottle)" into 100 ml flask, then, fill up to the gauge line with distilled water.

2.5 Gas Sampling Flask

The gas sampling flasks, around 1.2 litter inner volume, are used for this flue gas sampling method. Each flask need to be evacuated in laboratory before using them on site. There is no absorbing solution to put in flask for this method.

Sample gas is captured in evacuated flask on site.

2.5.1 Evacuation of Sampling Flasks

Prior to gas sampling, at least two gas sampling flasks must be prepared. Evacuate the flasks using small type suction pump until inner pressure reduced until around 30 kPa. Pay attention to the cock orientation and procedure of evacuation operation.

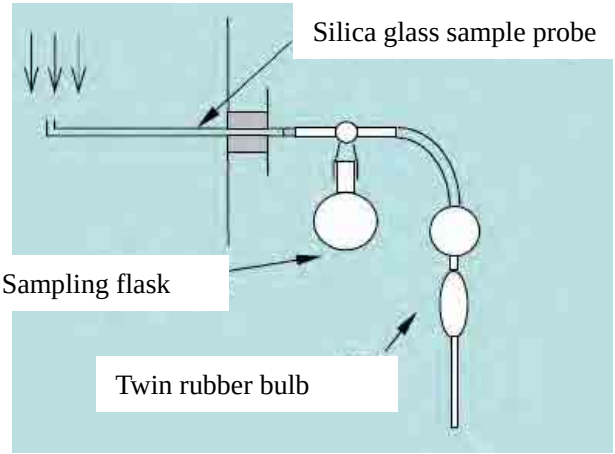
2.5.2 Measurement of Flask Inner Pressure and Surrounding Air Temperature

Measure the inner pressure of flasks evacuated by the pressure gauge. Record this reading as pre-sampling pressure Pi (kPa), along with laboratory room air temperature as pre-sampling temperature Ti centigrade. It must be measured for each flask and recorded on field notebook.

3. Gas Sample Collection at Monitoring Site

Suck the flue gas into a flask by its inner negative pressure according to procedures below. Sampling will be finished in short time.

1) Install the sampling apparatus at measurement hole. There must be no leakage in all sampling connection. More than two samples (flasks) must be taken.
2) Before start sampling, operate the twin rubber bulb, suction the sample gas into sample probe and glass connection unit until the moisture in the tube does not condense to water. The three way cock orientation must be  position.
3) Suction the sample gas into the sampling flask by turning the three way cock as shown by  .



4) After taking sample gas into flasks, measure and record the inner pressure of each flask and

room air temperature as same procedure as section 2.5.2.

Measure the inner pressure of flasks and record this value as post-sampling pressure Pf (kPa), along with laboratory room air temperature as post-sampling temperature Tf centigrade. It must be done for each flask and recorded on field notebook.

5) Take 5ml 'A' solution and 50ml 'B' solution, put both solution into the 100ml syringe. Any air must not be left inside the syringe. It is better to wear the laboratory groves to protect hands from alkaline solution.

6) In five minutes right after taking sample gas into flasks, connect the syringe to the flask as shown in picture below, then inject all solution in syringe into the flask. The three way cock orientation should be  .

(This work must be done on site)

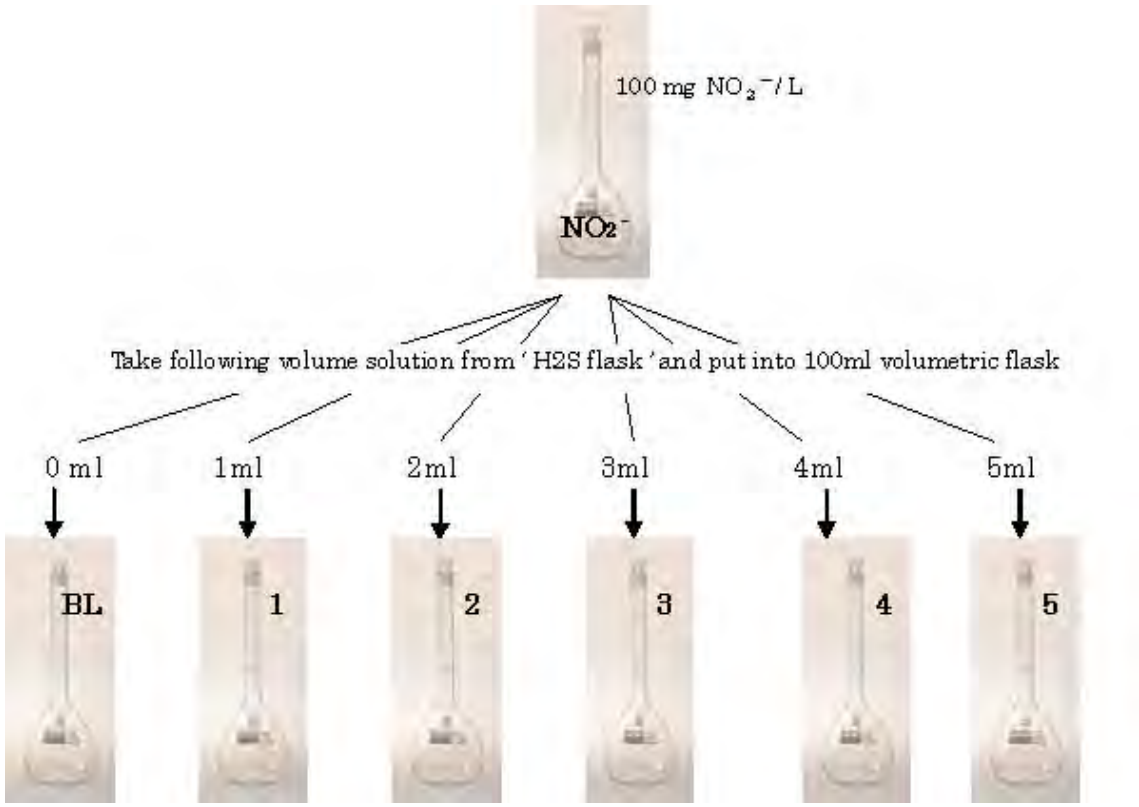
Close the cock as shown by  , after transfer all solution to flask, then disconnect the syringe.

7) Soon hold the flask by both hand, and shake it hard three minutes for mix to let NOx in sample gas be absorbed into solution. That's the end of on site work.

4. Analysis by Absorption Spectrophotometer

4.1 Preparation of Making a New Standard Curve for NOx Analysis

Put 0 to 5 ml of the solution for calibration curve of nitrogen dioxide (100mgNO_2^-/L) in several 100 ml measuring flasks stepwise.



Prepare six clean gas sampling flasks with no evacuation. Make the same operation to each gas sampling flask as shown in 5), 6), 7) in Chapter 3. Then, the mixed solution of each flask is transferred to corresponding 100 ml measuring flask respectively on which the number from BL to 5 is marked on the surface. Rinse inner surface of a flask using 15 ml distilled water twice, this rinsed liquid must be added to the 100 ml flask as the portion of sample. Each gas sampling flask needs same rinse operation respectively.

4.2 Transferring of the Sample liquid

Sample liquid brought from site should be transferred to the 100 ml measuring flask as same manner shown above as well.

4.3 Heating and Cooling Process for Samples

Put the running water into the Water Bath around half, adjust the temperature controller at 80 centigrade to warm up. Take off caps from every 100 ml measuring flask of standard sample from BL to 5 and retrieved samples taken from site, place flasks in water bath to warm up in 80 centigrade hot water around 30 minutes (gas will continuously come out from each flask because of chemical reaction).

Then, take the flasks out from the water bath, and cool the flasks by pouring the running water on outside the flasks. After cooling to room temperature, fill the flasks up to 100 ml gauge line with distilled water, then, put the cap to each flask and shake slightly in order to store them as the analysis sample.

NOx Analysis for Stack Monitoring

Measurement method; NEDA (Naphthyl ethylenediamine absorptiometry) by Absorption Spectrometer

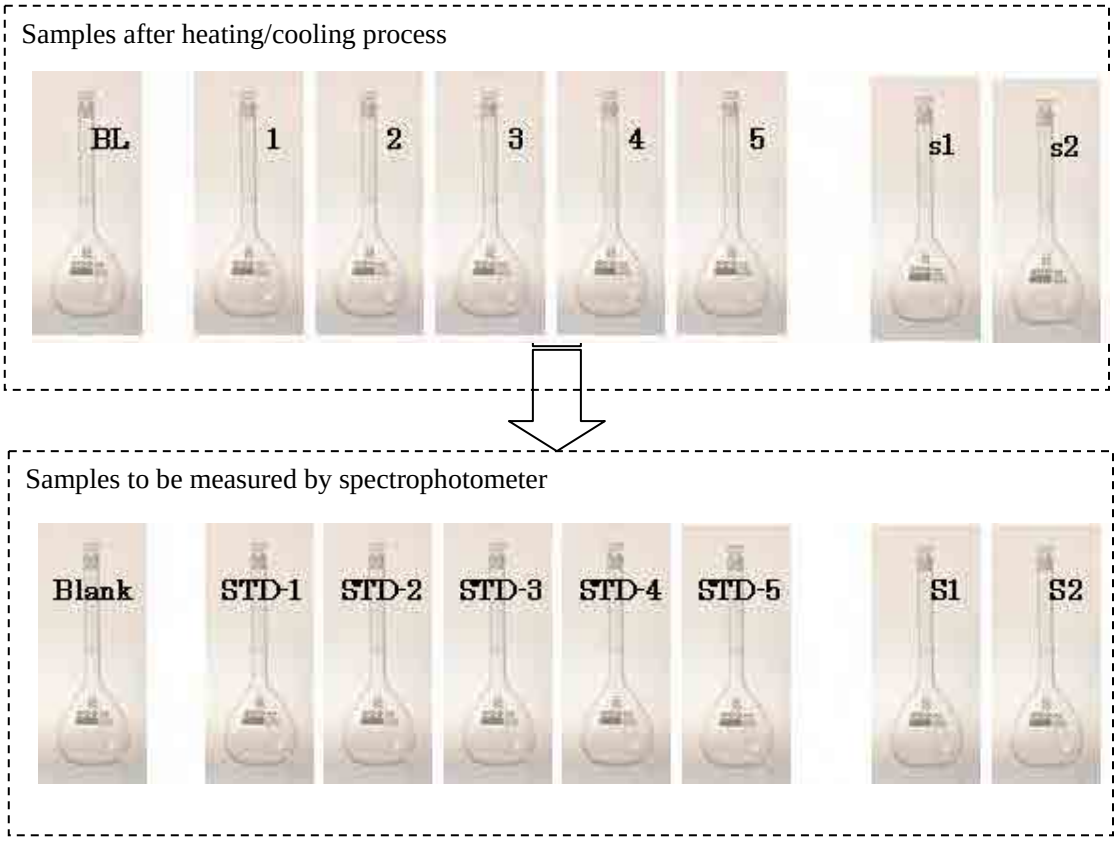
5. Coloration, Measurement by Absorptiometry

Prepare 8 pieces of new 100 ml measuring flasks. Take 20 ml sample liquid from analysis sample flask, and transfer it to a new 100 ml measuring flask. Then, add the two solutions shown below for each new flask.

① 10 ml Sufanilamide HCl Solution prepared at section 2.2.
② 5 ml Naphthylethylenediamine Solution prepared at section 2.3.

Then, fill the flask up to 100 ml gauge line, and shake them hard after putting the cap. Leave it is around 15 minutes in room temperature for final conditioning.

Measure the absorbance of samples by spectrophotometer at 545 nm wavelength.



6. Determination of the Sample Concentration

Concentration of Nitrogen Oxides in flue gas is calculated by two measurement results, sample gas volume taken and weight result of Nitrogen Dioxide absorbed in absorption liquid (alkaline solution).

6.1 Calculation of Sample Gas Volume Taken

Find the Dry gas volume according to the formula below:

$$V_{SD} = Va \times \frac{273.15}{101.32} \times \left[\frac{P_f - P_{nf}}{273.15 + t_f} - \frac{P_i}{273.15 + t_i} \right] \quad (\text{ml})$$

Where,

V_{SD} ; dry gas volume taken, converted at standard condition (ml)

Va ; capacity of gas sampling flask (ml) （the value printed on each flask）

P_f ; pressure in gas sampling flask after gas sampling (kPa)

P_{nf} ; saturated steam pressure at t_f℃ (kPa)

P_i ; pressure in gas sampling flask before gas sampling (kPa)

t_i ; room temperature when measuring Pi (℃)

t_f ; room temperature when measuring Pf (℃)

6.2 Calculation of Nitrogen Oxide Concentration in Flue Gas as Dry Base

$$C_V = \frac{0.487 \times V}{V_{SD}} \times \frac{100}{20} \times 10^6 \quad (\text{volppm})$$

$$C_W = \frac{V}{V_{SD}} \times \frac{100}{20} \times 10^6 \quad (\text{mg/m}^3)$$

Where,

C_V ; volumetric concentration of nitrogen oxides in flue gas (volppm)

C_W ; mass concentration of nitrogen oxides in flue gas (mg/m^3)

V ; mass of nitrogen oxides obtained by the aid of calibration curve (mg)

20 ; volume of sample liquid taken in accordance with Chapter 5 (ml)

0.487 ; volume of nitrogen dioxide equivalent to 1mg of Nitrogen Dioxide (ml)

4 Stack Gas Measurement Procedure for Power Plant Boilers

Capacity Development Project
for
Air Quality Control in Ulaanbaatar City, Mongolia

Stack Gas Monitoring Guideline
for
Coal Thermal Power Plant

November 2012

Contents

1. How to Use This Book

The JICA Project' Capacity Development Project for Air Quality Control in Ulaanbaatar City' measured air pollutants in discharged gas from boilers during two winter seasons in Ulaanbaatar City, and obtained representative data of their concentration and emission factors. The instructions and work procedures are shown in this guideline based on actual field monitoring for measurement of air pollutants emitted from a stationary source.

This HOB Stack Gas Monitoring Guideline is one of three Guidelines prepared for three typical pollution sources: 'Coal Power Plant, Heat Only Boiler (HOB) and Ger Stove.'

This book shows the entire stack gas monitoring schedule for a boiler in Chapter 6, and details of task procedures or instructions are shown in from Chapter 7 to Chapter 12 in order.

There are many complicated task procedures in this method; however, conventional measurement techniques are used. The details of task procedures such as the equipment operation procedures are separately summarized in other technical manuals as a reference, because the details of every procedure are not necessary all together in one book. The measurement rules commonly applied for three Stack Gas Guidelines are prepared as the 'Stack Gas Monitoring Protocol' shown below.

Table 1-1 Technical Reference Materials

No.	Material Name
1	Stack Gas Monitoring Protocol
2	Installation Procedure of Measurement Hole on a Chimney
3	Wet Sampling/Analysis Procedure for Gases
4	Moisture Measurement (Technical Manual)
5	Temperature Measurement (Technical Manual)
6	Flow Rate Measurement (Technical Manual)
7	Automated Stack Gas Analyzer TESTO (Technical Manual)
8	Automated Stack Gas Analyzer PG (Technical Manual)
9	Automated Stack Gas Analyzer HT-3000 (Technical Manual)
10	Automated Isokinetic Dust Sampler (Technical Manual)
11	Data Reduction Procedure (Technical Manual)

2. Purpose of Stack Gas Monitoring

In Mongolia, hot water necessary for people's daily living and their industrial activities is produced mainly by burning coal in thermal power plants, small boilers (HOB, CFWH), and household stoves.

The thermal power plants constitute the core of the large-scale hot water supply network for the central part of the city. In areas without the supply of this hot water, each city block is provided with a small boiler and forms a zonal heating system using the boiler. Thereby, the hot water is supplied to ordinary houses and public facilities (schools, hospitals, etc.) in the vicinity of the small boiler. In the surrounding areas and some isolated areas that do not even have this type of hot water supply network, coal stoves are used in ordinary houses and ger.

Air pollution becomes heavy in winter and is considered to be generated mainly by the combustion of coal in these fixed generation sources. In order to reduce the pollution, it is necessary to regularly measure the amount of air pollutants discharged from the fixed discharge

sources.

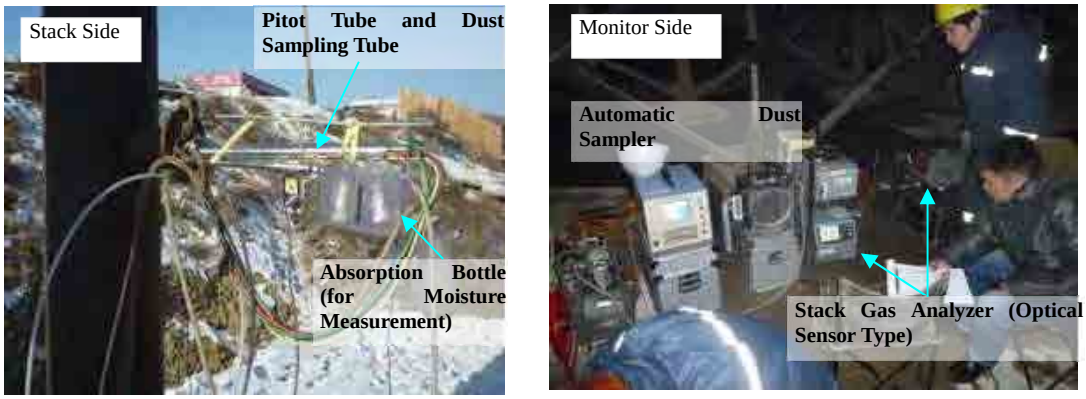


Fig. 2-1 Stack Gas Monitoring

3. Features of Monitored Boiler

Coal Thermal Power Plants are the major source of supplying the electricity, hot water and steam in Ulaanbaatar City, their operation are never stopped in any season to provide the energy of heat and electricity required for civil life and Industrial activities.

The hot water is used for heating rooms, cooking, washing, and even for factories where steam are used for manufacturing process. Discontinuation of the supply of hot water is vital for the people and, therefore, there are heating energy demand over 8 months per year from the late of chilly September through late spring June. Boiler peak operations are during severe winter days.

A thermal power plant generally has several numbers of furnaces. The operation plan of furnaces is arranged daily according to the anticipated demand of electricity and hot water, controlling the product capacity of steam for each boiler. The number of boilers in operation will be reduced in summer season due to the decreased demand of total energy.

Trouble may happen on boilers and affect the energy demand, however repair for boilers are carried out at every summer. Therefore, the usual maintenance, preventive and periodical, are required as sound operation control which enable them to use in alternative work schedule.

3.1 Outline of Thermal Power Plant

Table 3-1 through Table 3-4 show the outline of the Coal Thermal Power Plant and their photos.

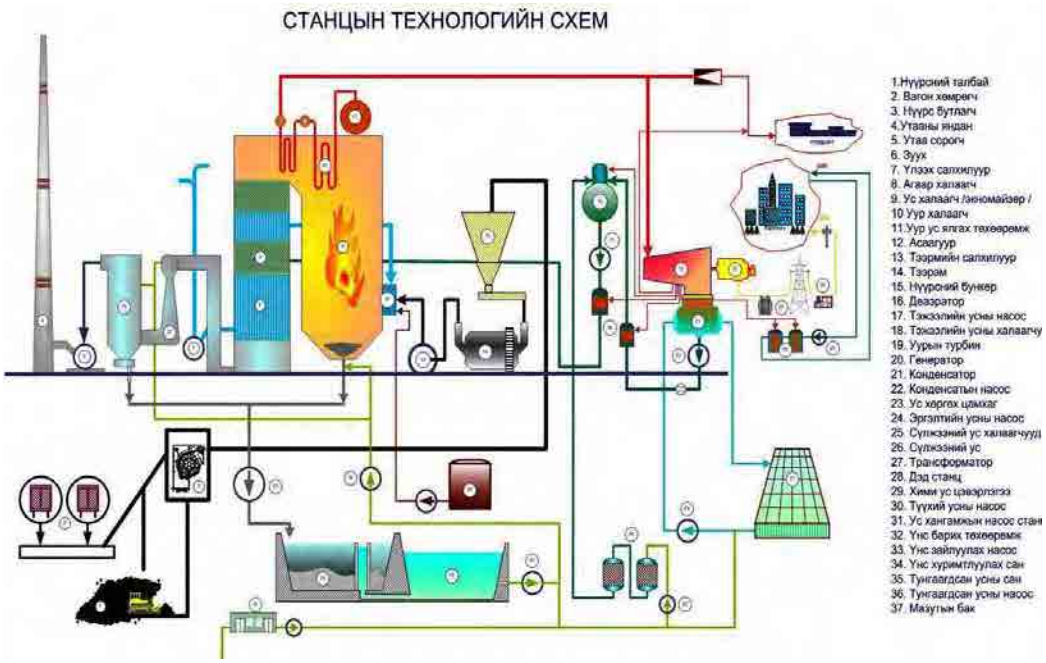


Fig. 3-1 Outline of Coal Thermal Power Plant at PP3

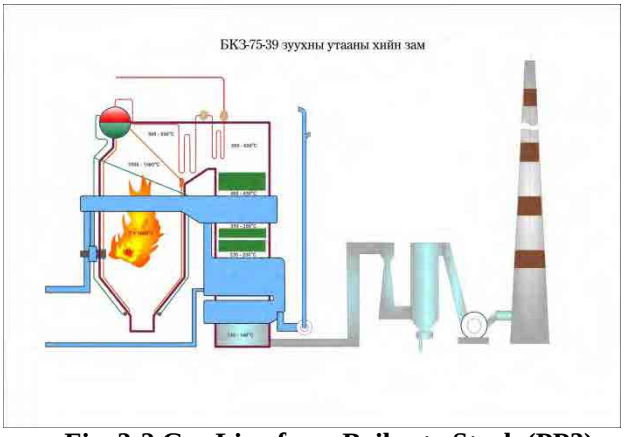


Fig. 3-2 Gas Line from Boiler to Stack (PP3)

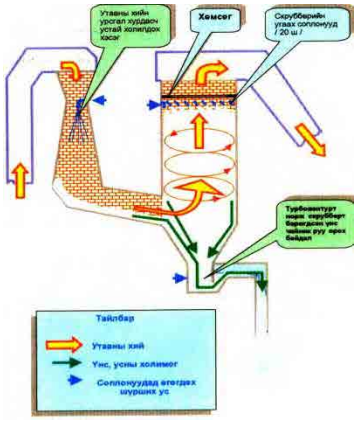


Fig. 3-3 Stack Gas Scrubbing System (PP3)

Fig. 3-4 Control Room (PP3), 35 t/h Boiler (PP2)

Fig. 3-5 EP (PP4), Cyclone / Venturi Scrubber (PP3, PP2)

Fig. 3-6 Measurement Hole for Stack Gas Monitoring (PP4, PP3, PP2)

3.2 Structural Factors Influencing Flue Gas Conditions

Table: 3-2 shows the major operational factors that influence the flue gas measurement value. The 'structural factors' in this table correspond to the contents in Section 3.1. Both structural and operational conditions influence the amount of discharged pollutants.

Table 3-1 Factors Influencing the Flue Gas Conditions

	Structural Factors	Operating Factors
Coal Feeding	Automated type	Time interval Amount (related to hot water demands) Size, kind and components of coal
Ventilation	Balanced type	ON-OFF timing Adjustment of damper travel
Gas Treatment Unit	Cyclone, Wet scrubber, EP	Maintenance condition
Others	Boiler types, Maintenance	Operation control

4. Measured Items and Measuring Equipment

'Measurement Items and Methods' and 'Outline of Measurement Equipment' are respectively described in Chapter 4.2 and Chapter 4.3.

The equipment for gas analysis and dust sampling should be chosen according to its merits, as shown below.

4.1 Differences between Two Types of Gas Sensors

The upper half of the following table shows the differences between two types of gas sensor methods. To evaluate the measurement accuracy and reliability of the values reported for each method, the lower half of the table gives one of the three grades: 'high, middle, and low.'

Table 4-1 Performance Difference between Stack Gas Analyzers

Sensor Type of Stack Gas Analyzer		Chemical Sensor	Optical Sensor
Feature	Concentration range	Covers both low and high concentration range.	
	Deterioration of sensor	Easy deterioration in high concentration interference gas.	Robust
	Measurable time range in continuous monitoring	A few minutes especially in high concentration CO gas	Long time range (hours) in every gas condition
Data Collection	Total number of data and sampling timing	Three data for a boiler at random timing	Hundreds of data for a boiler Every 10 seconds during the whole sampling time
Calculation of Reporting Value	Calculation of the average concentration	Average of few data	Averaging hundreds of data
	Calculation of the average concentration (after O_2 conversion)	Unsatisfactory representative result due to few sampled O_2 data	Good representative result based on hundreds of sampled O_2 data
Quality of Measurement Accuracy	At calibration	Middle (Sensor sensitivity degrades gradually during several months by being affected by interference from sample gases.)	High
	Appropriateness of the gas sampling method	High	High
Validity of Sampling Condition Chosen	Setting of the measurement timing	Low	High
	Sampling time period	Low	High
Reliability of Report Value (Gas Concentration)	Calculation accuracy of O_2 conversion value	Low	High

Chemical Sensor Type　　Optical Sensor Type

Figure 4-1 Stack Gas Analyzers Used

4.2 Differences between Two Types of Dust Sampling Equipment

Table 4-2 Differences in Equipment Performance/Use and Data Calculation for Dust Sampling

Type of Dust Sampling Equipment		Manual Type	Automatic Type
Use	Isokinetic sampling control	Read out the gas condition every two seconds, and adjust the sampling speed manually	Continuous automatic control
	Total number of data sampling timing	Three samples for a boiler, taking around 20 minutes for a dust sample. The sample timing and time length are to be determined by actual operative information of a target boiler.	
Calculation of Reporting Value	Calculation of average concentration	Arithmetic mean of three data	Time-weighted average concentration of three data
	Calculation of average concentration (after O_2 conversion)	Unsatisfactory representative result due to few (three) sampled O_2 data	Good representative result based on hundreds of sampled O2 data
Operability	Quickness of control	Middle	High
	Accuracy of control	Middle	High
Validity of Sampling Condition Chosen	Start timing	High	High
	Sampling period	High	High
Reliability of Value for Reporting (Dust Concentration)	Calculation accuracy of O_2 conversion value	Middle	High

Manual Type

Automatic Type

Fig. 4-2 Dust Samplers Used

4.3 Features of Equipment for Measurement in Winter

Special care should be taken to prepare equipment for out-door monitoring in Ulaanbaatar City because the temperature can fall to minus 30 or 40 degrees in a severe winter season.

Table 4-3 Freeze Prevention for Monitoring Equipment

No.	Name	Method
1	Inclined Manometer	Use an anti-freeze solution as the inner liquid such as ethyl alcohol.
2	Gas Meter	Use the dry type gas meter. If the wet type is used, it will require anti-freeze solution.
3	Power Cable	Use a cold-resistance power cable to prevent short circuit problems due to a hard frozen cable malfunctioning.
4	Gas Sampling Tubes (Connection Cables between Chimney Side and Analyzer Side)	Use a silicon braid hose for moisture and dust measurement. A Teflon tube must be used for gas component measurement.
5	Trap Box	Use plastic bottles to prevent the moisture in the sample gas from concentrating and freezing inside the sampling tube for gas or dust measurement use.
7	Heat Resistant Material	Wrap the sampling tube with insulation piping.

5. Technicians for Measurement

The technicians to perform the stack gas measurement must satisfy the following requirements:

Table 5-1 Qualification for Stack Gas Monitoring Technician

No.	Requirement
<As the capacity of a monitoring team>	
1	The team must be the owner of stack monitoring equipment as shown in Chapter 4, or should be an organization that has the capacity to borrow the equipment.
2	Owner of a laboratory, or the person who has the capacity to use a laboratory as a work place for weighing samples or maintaining equipment.
3	Capable of procuring a van to carry the equipment to the monitoring site.
4	Capacity to assign two or more experienced technicians for the stack monitoring work on a boiler. (Beginners must not be counted as experienced staff members.)
5	Self-management capacity to generate a report voluntarily and honestly when problems occur with the monitoring equipment during its use. Capacity to pay to fix malfunctioning equipment.
<Personal Qualification>	
1	A person who participated in the training course of stack gas monitoring in a JICA project, or has rich experience of performing actual monitoring in power plants or on HOBs.
2	More than 30 times of monitoring experience on site
3	Capability to operate the isokinetic dust sampling
4	A high level of understanding to use the dedicated dust calculation software.

6. Monitoring Steps

An overview of the boiler stack gas monitoring steps for the boiler will be described. The monitoring steps on the day are detailed and will be described in Section 6.1.

Table 6.1 Monitoring Steps and Contents of Monitoring

No.	Time	Contents
1.	Preparation	① Notification and coordination of monitoring schedule for the manager of the target boiler ② Verification of measurement site by preliminary inspection ③ Arrangement of vehicles and drivers to carry the equipment ④ Provision of necessary supplies of consumables. ⑤ Confirmation of equipment status
2.	The Previous Day of Measurement Day	① Selection of equipment used for stack gas measurement ② Maintenance for: e.g. absorption bottle, trap box ③ Conditioning and pre-weighing of dust filters ④ Preparation of field recording sheets ⑤ Equipment preparation for loading
3.	Measurement Day	See Section 6.1
4.	The Next Day of Measurement Day	① Post-weighing of filter with sampled dust for dust measurement ② Data reduction and report production

6.1 Example of Monitoring Schedule on Measurement Day

An overview of the monitoring will be described following the flow of the measurement work for one day.

Some of the steps from the installation to the ending of the monitoring differ depending on whether manual operation equipment or automated equipment is used, as shown in Table 6-2.

Table 6-2 Work Flow on Measurement Day

<table>
<tr><th rowspan="2"></th><th rowspan="2">No.</th><th colspan="2">Work Flow</th></tr>
<tr><th>With Manual Operation Equipment</th><th>With Automated Equipment</th></tr>
<tr><td rowspan="3">Transportation</td><td>①</td><td colspan="2">Loading of the equipment on the carrying vehicle.</td></tr>
<tr><td>②</td><td colspan="2">Departure to the target boiler.</td></tr>
<tr><td>③</td><td colspan="2">Arrival at the target boiler.</td></tr>
<tr><td rowspan="4">Verification of Monitoring Site</td><td>①</td><td colspan="2">Greeting to person in charge of the power plant. Verification of room layout and work space for equipment installation inside/outside the boiler house.</td></tr>
<tr><td>②</td><td colspan="2">Unloading and shifting of the equipment at the measurement site (the monitor side and the chimney side).</td></tr>
<tr><td>③</td><td colspan="2">Preparation of power supply. Cleaning of the work place for equipment installation.</td></tr>
<tr><td>④</td><td colspan="2">Interviewing the operator (about general information of the boiler, operating schedule on the measurement day, the coal type, etc.). Record the information as a field note.</td></tr>
<tr><td rowspan="3">Installation & Warming-up of Equipment</td><td rowspan="2">①</td><td colspan="2">Determination of the equipment setting position inside the room. Performing the piping and wiring task between the monitor side and the chimney side.</td></tr>
<tr><td>Equipment: Gas meters, inclined manometer, etc.</td><td>Equipment; Gas meters, automated isokinetic sampler, etc.</td></tr>
<tr><td>②</td><td colspan="2">Warming-up of the stack gas analyzers. Turn ON the electric heater if it is cold inside the room.</td></tr>
</table>

	③	Confirmation of the operability of the suction pump and the PC in the working environment.	
	④	Weighing of the absorption bottles as pre-weighing. Record as a field note.	
	⑤	Open the cap of the measurement hole on the chimney. Rake the accumulated ash and clean the inside of the pipe. Attach the supporting rod on the flange of the measurement hole. Arrange the piping and the wiring of sampling tubes, the temperature signal code and the power cable.	
	⑥	Measure the chimney inner radius and the flange length protruding from the chimney, and record them as a field note.	
	⑦	Calculate and record the measurement position on the cross-sectional area according to the size data of the chimney.	
	⑧	Wind pieces of adhesive tape around the sampling tube or the Pitot tube to mark the sampling positions where the tips of the sampling inlet are to be set on a cross-sectional area in a chimney.	
		Pipes to be marked: Pitot tube and dust sampling tube	Pipe to be marked: Only the integrated dust sampling tube
	⑨	Start up the PC and open the designated calculation sheet (Excel). Input the facility information and the measured atmospheric pressure value.	
		Use the calculation sheet for manual sampling. Use the dedicated barometer to measure the atmospheric pressure.	Use the calculation sheet for automated sampling. The automated dust sampler indicates thereon the measured value of atmospheric pressure.
	⑩	Join the tubes from the chimney side with tubes from the monitor side. Put the drain trap box into both the dust sampling line and the gas measurement line. Take measures against the cold climate to avoid moisture freezing inside the tubes. Check the leakage of the tubes.	
	⑪	Insert the sampling pipes for the gas measurement and the moisture sampling, and the temperature sensor. Using heat resistant tape, fill the gap between the hole and sampling pipes.	
	⑫	Determine the starting and the/ending timings for the dust or the moisture sampling based on the information gathered from the boiler operators. Record the coal feeding and turning ON/OFF timings of the fan until the end of the dust measurement.	
	⑬	Calibrate the stack gas analyzers by introducing reference gases. Then, start measurement of gas measurement items in the 'measurement mode.'	
Basic Measurement	①	Measure and record the temperature of the flue gas.	No basic measurement is required when the automated dust sampler is used.
	②	Measure and record the flue gas speed.	
	③	Take the moisture samples. Weigh the samples and record the results.	
Dust Sampling	①	Input the results of the basic measurement into the designated spreadsheet. Measure new static/dynamic pressures and the temperature of flue gas, and input those data again. Calculate the isokinetic sampling speed of the dust and determine the nozzle inner diameter to sample the dust. Fit the sampling probe into the measurement hole after assembling the sample head.	Determine the nozzle inner diameter for the dust sampling according to the displayed data such as flue gas speed, etc. Assemble the moisture sampling apparatus and install it in the measurement hole.
	②	Take three dust samples according to the guideline 'Stack Gas Measurement Protocol.'	
		Read out the instantaneous value of the dynamic pressure and the temperature displayed on devices every one minute, and adjust the sampling speed frequently.	The dust sampling is controlled automatically. Moisture sampling must be performed at the same timing as dust sampling.
	③	Keep the dust sample filter in the dedicated glass holder, and finish the entire measurement.	

Withdrawal	①	Retrieve the record sheet, the samples and the memories. Demount and reassemble the integrated equipment at both the chimney and the monitor sides and re-load all in carrier vehicle.
	②	Clean the place where the equipment was installed. Let the boiler operator know that you have finished work and are leaving.
Storage	①	Put the equipment back in its original position on the shelves in the office. Place the record sheets in a file. Check the condition and conduct maintenance work for the equipment if it is required.
	②	Keep the dust sample filters in the desiccator after drying them in a drying oven.

6.1.1 When Manual Operation Equipment Is Used

Figure 6-1 shows an example of the monitoring steps for the day of measurement. The item numbers in Fig. 6-1 correspond to those in Table 6-2.

Because the operation conditions and the stack inner diameter differ for each boiler, the time necessary for conducting the basic measurement and the dust sampling may be longer than that in the table below. When the gas components are collected and analyzed using the moisture sampling, the basic measurement and the work back in the laboratory after the sampling shall additionally be conducted.

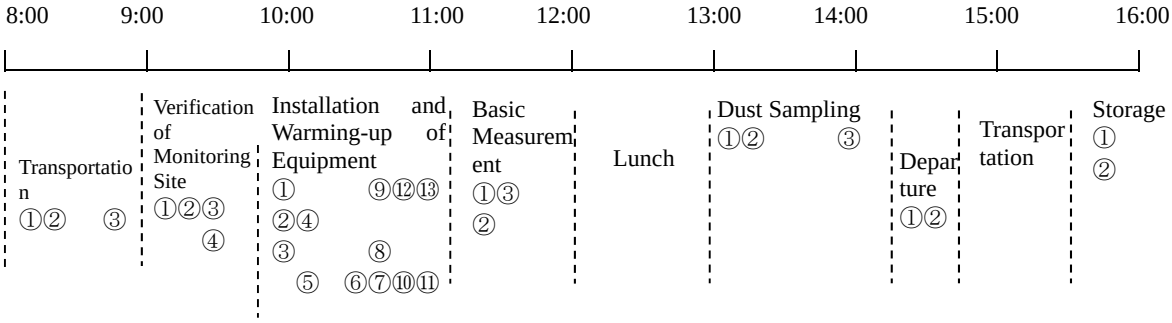


Fig. 6-1 Flow of Monitoring on Day of Measurement

6.1.2 When Automated Equipment Is Used

The monitoring steps are almost the same as those for using manual operation equipment apart from the absence of basic measurement, etc.

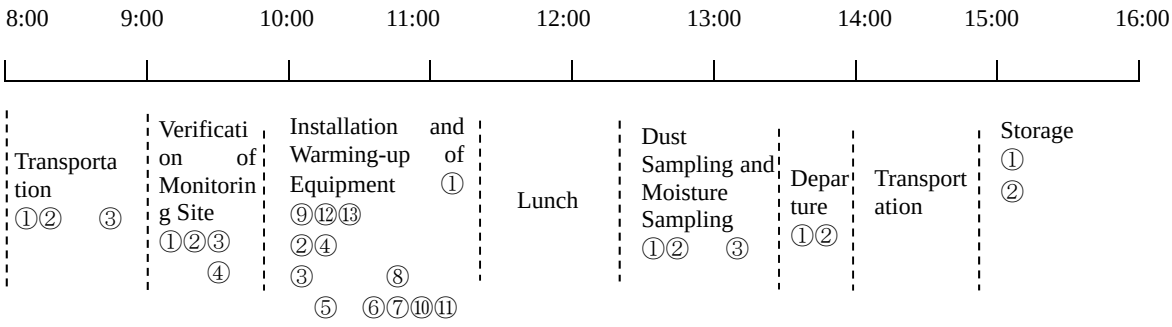


Fig. 6-2 Flow of Monitoring on Day of Measurement

7. Preparation before the Day of Monitoring

Before the day of the measurement, communication with external organizations, preparation and checks on the equipment to be used, etc., are conducted. This preparation is important for efficiently conducting the monitoring and avoiding mistakes on the measurement day.

7.1 Pre-Arrangement

7.1.1 Preparatory Notification to the Manager of the Boiler Facility to Be Monitored and, Coordination and Determination of the Day of Measurement

At least 10 days before the measurement day, call the thermal power plant for which the measurement is planned and request permission for measurement. Obtain as much information as possible from the operator to check whether the boiler is operating normally with no malfunctions and that the boiler will be in operation as usual on the day of the measurement. Based on the outcome, the steps planned by both sides are checked to determine the day of the measurement.

For boilers on thermal power plant, permission to visit must be applied for in writing. It takes time to obtain permission (one week or more). Send the request letter for it soon after the measurement day is determined.

7.1.2 Verification of Monitoring Site

When the day of the measurement has been determined on the phone, the state of the site should further be checked on the phone such as whether the space for the measurement work can be secured. For the facility to be measured for the first time, a preliminary visit should be made before the actual measurement.

Some sites may impose the following difficulties on the measurement work:

Table 7-1 Points to Be Checked in Preliminary Visit to Site

Defect	Countermeasure
The duct has no measurement hole.	According to the Guideline "Installation Procedure of Measurement Hole on a Chimney," newly install the hole.
The measurement hole is installed at a high position and it is dangerous to use it.	The stack shall be excluded from the stacks to be measured.
The scaffold around the duct is dangerous.	

7.1.3 Arrangement of Vehicles and Drivers to Carry Equipment

Vehicles to be used on the day of measurement (for monitoring technicians and to carry the equipment) and drivers for them shall be secured in advance. Employment agreements with them shall be concluded also in advance when necessary.

7.1.4 Provision of Necessary Supplies of Consumables, etc.

In the monitoring, the consumables shown below (examples) are used. Therefore, sufficient consumables shall be supplied.

Dust filter, plastic tape, wire, silicone tube, silica gel, $CaCl_2$, cotton work gloves (which shall be reused after washing to the extent possible)

It shall be confirmed early that no device is faulty.

7.2 Preparation on Previous Day of Measurement

7.2.1 Selection of Equipment to Be Used

The features of the performance of the main devices are as shown in Chapter 4. Table 7.2 shows simplified options for each of the devices.

A combination of the automated stack gas analyzer and the automated isokinetic dust sampler is determined as the best combination taking into consideration the large number of data collected, the measurement precision, and the simplicity of measurement work.

Table 7-2 Features of Manual Operation and Automated Devices

Use of Device	Name of Device	Feature
Gas Speed Measurement	Inclined manometer (as a pressure gauge)	The operation is complicated and the accuracy is low.
	Automated isokinetic dust sampler	Operation and recording are automated and the accuracy is excellent.
Analysis of Gas Components	Wet type gas sampler (SO_2, NOx)	Only one piece of data can be obtained and it is difficult for this data to represent the status.
	Stack Gas Analyzer (TESTO)	Few data can be obtained and it is difficult for these pieces of data to represent the status.
	Automated Stack Gas Analyzer (PG-250) Automated Stack Gas Analyzer (HT-3000)	The data can continuously be obtained and the data has high capability as representative data.
Dust Sampling	Manual isokinetic dust sampler	The gas speed and the temperature vary significantly in a coal boiler. The manual control of these items tends to be inaccurate. Therefore, the accuracy is intermediate.
	Automated isokinetic dust sampler	The control is automated and the accuracy is relatively high.

7.2.2 Maintenance of Equipment Used, and Pre-Process and Pre-Weighing of Dust Sampling Filter

The preparation of the dust-sampling filter shall be started in the morning of the previous day of sampling. The following operations shall be conducted on new cylindrical filters (Five or more filters shall be prepared for one boiler):

Table 7-3 Preparation Procedure for Dust Cylindrical Filter

No.	Preparation Procedure for Paper Filters
1	When the stack gas temperature is low, select glass-fiber cylindrical filters. When the stack gas temperature exceeds 200℃, select silica-fiber tube-type paper filters.
2	Provide each of the cylindrical filters with a serial number (see the filter weighing sheet). Handle the filters with clean hands to avoid dust contamination.
3	Place the cylindrical filters longitudinally in a beaker (with their openings upward) and put the beaker as it is in an oven.
4	Dry them in the oven at 110℃. Turn OFF the oven after one hour and leave the beaker to cool.
5	When the beaker is somewhat cooled, move the beaker with the paper filters in it using a pair of tongs into a dedicated desiccator.
6	Leave the beaker to be cooled in the desiccator as it is for two or more hours in its dry state until the temperature of the filters becomes room temperature.
7	Take one of the filters out of the desiccator and immediately weigh each filter using a 10^{-4}-g scale. Record the weight of the filter as a pre-sampling weight with the filter number.
8	Store the filter after weighing it. Place the filters in the cylindrical filter case (the dedicated glass bottle) or the case that has been storing the new paper filters.

Silica Filter

Dryer


Filters are dried.


The paper filters are cooled in the desiccator to room temperature.

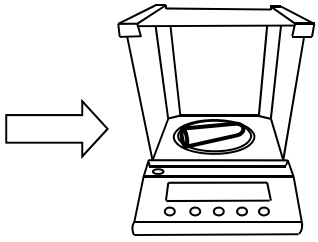


Fig. 7-1 Preparation of Dust Paper Filter

As the maintenance of other devices, for example, the following checks, cleaning, etc., shall be conducted:

Table 7-4 Important Points of Device Maintenance

Clean the dust-sampling nozzle. Check the presence of packing of the dust sampling tube.
Maintenance of absorption bottle (Sheffield bottle): When 1/3 of $CaCl_2$ is dissolved, replace the bottle. When the portion around the cock is clogged with silicone grease, clean the clogged portion. Remove the stain on the gas inlet. Conduct checks on leakages and clogging.
When the inclined manometer is used; Check whether the alcohol is present.
Oil Pump: Discharge only the contaminated oil. Check whether the position of the oil level is normal and, when the oil is insufficient, replenish with new oil.
Dry-Type Gas Meter: When no temperature is displayed, replace the battery.
Stack Gas Analyzer: Check whether a significant shift is observed for the response value when the reference gas is introduced.
Check whether any of the pipes is clogged with water or dust. When any leakage is found, cut off the leaking portion.
Check the inexpensive electric appliances (such as plugs and electric heaters) have no disconnected wires.

7.2.3 Preparation of Field Recording Sheet

Each field recording sheet (in Mongolian) is prepared. Make copies from the original sheet.

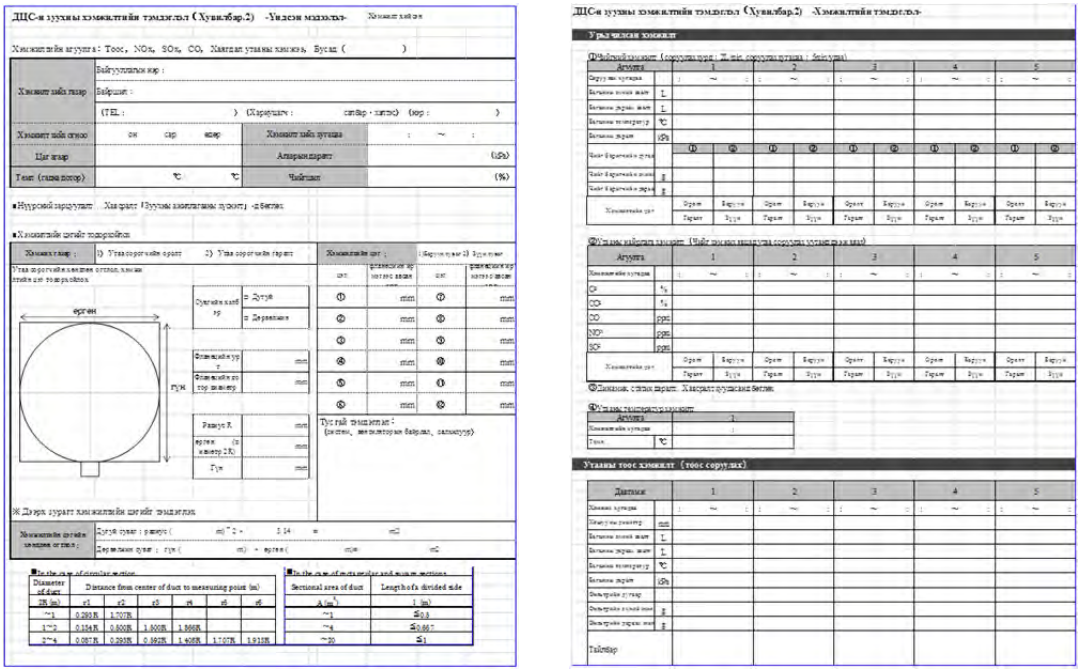


Fig. 7-2 Field Recording Sheet (Example)

7.2.4 Preparation for Carrying Equipment

If the devices were gathered in the morning of the day of the measurement, there would be insufficient time. All the devices to be used shall be prepared and gathered in the machinery room on the previous day. Use the device checklist to ensure that no necessary devices are left behind.

8. Work Steps to Be Performed before Measurement (Day of Measurement)

The procedure and remarks will be described for each work step according to the order of items in Table 6-2.

8.1 Move to Boiler

On the previous day, load all the devices collectively put in the machinery room, onto the device carrier vehicle. Move the devices quickly using a dolly to avoid breakages.

Fig. 8-1 Loading of Devices

Pay attention to the following items when loading the device on the vehicle:

Table 8-1 Points Requiring Attention in Loading Devices on the Vehicle

Carefully arrange the devices to be put in the cargo room on the vehicle to avoid damage caused by driving on bumpy roads.
Do not crush soft items by putting hard items on them or next to them.
Use cushions for fragile items and put the fragile items in baskets to the extent possible.
Always put precision instruments in their dedicated carry boxes.
Using ropes, fix items to avoid movement when the vehicle drives on bumpy roads. Otherwise, sandwich these items between heavy items.

When the vehicle is involved in heavy traffic after starting from base, contact the manager of the boiler to inform the manager of the delay and the estimated arrival time.

When the condition of the road surface is bad, drive the vehicle slowly to avoid breaking the devices loaded thereon due to bumps on the road.

8.2 Checks to Be Conducted on Site (Immediately after Arrival)

8.2.1 Greeting, Checks on Working Space, Carrying-in of Devices

After arrival, take time to greet the operators and obtain permission to enter the premises. After obtaining permission, drive the vehicle into the premises.

The leader of the measurement team shall observe "the space for monitoring equipment and the vicinity of the stack" and shall check the spaces in which to install the devices (because the measuring devices are installed being divided into two for the two positions of the stack side position and the monitoring side position).

The positions shall be determined under consultation with the boiler operators taking into consideration the size, the location, the piping of each working space not to interfere with the work of the boiler operators.

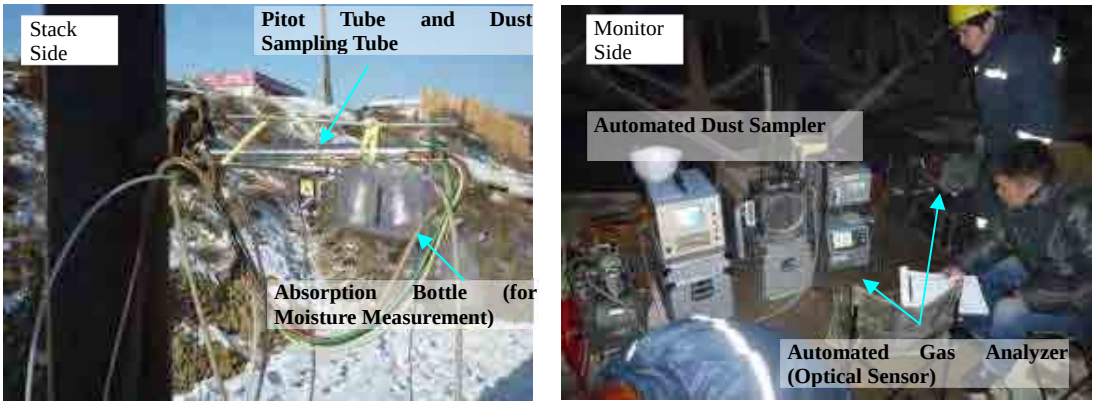


Fig. 8-2 Representative Example of Device Installation

The size of the boiler room and the positions of the measurement holes differ depending on the facility and, therefore, the arrangement of the devices is changed as follows according to the place.

Table 8-2 Difference in Device Installation Space

Case	Stack Side	Monitor Side
1	The measurement hole is located inside the room and all the monitoring steps can be conducted in a warm room. These are excellent conditions.	
2	The measurement hole is located on the stack outside the building and the devices for the stack side have to be installed around the stack.	There is enough indoor space for working.
3		No working space can be secured in the room and the measurement has to be conducted with the devices for the monitor side loaded on the vehicle. Two vehicles are necessary.

It is necessary to put the stack gas analyzers, the oil pump, the PC, etc. in a warm room for them to operate. In the winter in Mongolia, air pollution becomes heavy and the temperature may fall to -30℃. When cold air enters the room, the temperature may fall to -10℃ or lower. In this operation environment, some devices may lack measurement precision even though they seem to operate. Therefore, care must be taken to select the places in which to install the devices.

Fig. 8-3 Difference in Installation Place for Stack Gas Devices

Take care of the following points when the measuring devices are installed close to the boiler:

Table 8-3 Points to Requiring Attention in Selecting the Installation Positions

Observe the behavior of the boiler operators. Taking into consideration the behavior of the measurement technicians, the devices must be installed in positions that do not interfere with the boiler operators and the measurement technicians.
The position must have electric outlets available for the measurement and must be within the range for the power cable to reach.
The positions must allow the piping and wiring to be installed to connect the stack side and the monitor side.
The positions must be free from dripping water and secure from large trash falling on the measuring devices.

The room must be ventilated so that smoke from the boiler does not accumulate in the room.
The positions must be away from any rotating fan motor (especially, the rotational belt).
The positions must be away from the boiler to prevent overheating.
The scaffold on the stack side: The scaffold must be installed in a sufficient space that is not slippery, too high, or easy to fall from.

Ask the boiler operators where the electric outlets are (two or more outlets are preferable) and secure the power by connecting the power source drum to the outlets. After determining the installation positions, remove any trash and obstacles around the installation positions.

8.2.2 Interview for Facility Information, Operation Schedule, etc.

When the installation positions of the devices have been determined and the carrying of the devices has started, the leader of the measurement team shall interview the boiler operators to obtain information on the facility operation. Simultaneously, the information shall be recorded on the record sheet (see the table on the right).

Based on this information, the measurement schedule shall be determined for the day of the measurement (the starting time of the measurement and the length of sampling time).

Ask the staff of control room to write down the boiler operation condition in hourly record sheet.

The information obtained in the interview will be useful when the validity of the calculated report value is verified in the data reduction conducted on a later day.

1) Operation Policy for Day of Measurement

Is the combustion of the coal close to that in winter or is it suppressed in comparison?

2) Boiler

The model, the coal feeding method, the discharged gas treatment scheme (dust removal and desulfurization), and checks on faulty parts

3) Coal

Place of production, type, size.

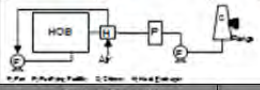
No.		1	
HOB Model		0000	
Photograph		 HOB  Stack	
System (for one stack)			
Item for Record		Content (Example)	Remarks
Basic Item	Place of Installation	0000	
	Date of Visit	Jan. 28, 2012	
	Temperature of Day of Visit	Average: -23 degrees (Max.: -13 and Min.: -31)	
Specification of Boiler	Capacity (MW)		
	Date of Installation		
	Quantity	One	
	Fan Type	Equivalent	
	Coal Feeding Type	Manual	
	Measurement Hole Position	Stack	
	Dust Sampler Type	Cyclone	
	Desulfurizer Type	None	
State of Operation	Supplied Water Set Temperature (℃)	80	
	Fan Operation Scheme	Intermittent Operation	
	Timings to Turn ON and OFF Fan	Fan is turned OFF when the returning water is 80℃ or boiler, and is turned ON when the returning water is around 70℃.	
	Leakage into Stack, etc.	A slight blowout before the stack	
	Use of Damper	Not verifiable	A damper is used.
	How to Put out Clinker	Pushing out into a clinker receiver behind the HOB	
	Frequency of Clinker Removal	Before every coal feeding	
	Frequency of Raking Coal	Several times an hour	
	Maintenance of Dust Collector	Cleaning once in a half day	
Items of Fuel	Type of Coal	Natalik	
	Size of Coal	Powder coal	About several centimeters
	Container to Feed Coal	Shovel	
	Coal Feeding Time Interval	Once in 20 minutes for about 10 shovelfuls	
	Feeding Amount at Time of Visit (kg/h)	220	
	Midwinter Feeding Amount (kg/h)	270	
	Other Items to Burn	Sometimes, paper trash	
Demand for Hot Water	Demand Origin	Schools, hospitals, and houses around the boiler	
	Demand Time Zone	All day long (no supply discontinuation)	
Other Items Observed or Interviewed		- The coal is fed such that the thickness of the coal on the fire grate is 8 to 12 cm. - The Inaba HOB is operated only in the cold season. - The coal is supplied to plural HOBs each at a different timing from each other. - Coal feeding is regulated based on the observation of the quality of the ash.	

Fig. 8-4 Example of Boiler Information Record

8.3 Installation and Warming up of Equipment

The place for installing each device differs depending on: the composition of the devices and the layout of the facility; and which devices are used. The installation and the warming up of the devices depend on whether the devices used are manually operated or automated and whether the position of the measurement hole is inside or outside the facility.

8.3.1 Safety Measures

8.3.1.1 Items to Wear

Fig. 8-5 Items for Workers to Wear

8.3.1.2 Points Requiring Attention when Working in High-Places

Generally the large-scale facility of power plant have a high stack and may also have a measurement hole at a high position located 10 or more meters from the ground. The stack-side devices described in Items 8.3.2 and 8.3.3 shall be installed around the measurement hole and the piping and the wiring (such as the power cables and the temperature compensating conductors) are also installed around it.

Install the stack-side devices using ropes and take the safety provisions into consideration. Lift the devices with two persons as a team synchronizing the timing between the two by using a sign.

<Stack Side> Check the scaffold carefully. Tie the end of the rope to a rail of a fence, etc. Wind the unused portion of the rope tightly not to obstruct the work and to avoid fouling of the rope on the legs of the technicians.

When an article is lifted up, lift the article slowly directly upward to avoid the article swinging.

<Monitor Side> Wind the rope once around the device to be lifted (if the rope is tied at only the handgrip of the device, the lid of the device may open and the articles retained therein may fall out). When the lifting has been started, the persons standing under the device must move away to avoid standing beneath the device.

When a pipe lifted up is fixed, take into consideration the position to fix the plastic pipe to avoid being squashed by its own weight.

Correctly Fixed

Incorrectly Fixed: The pipe gets squashed by its own weight where it is fixed.

Fig. 8-6 How to Fix the Pipe

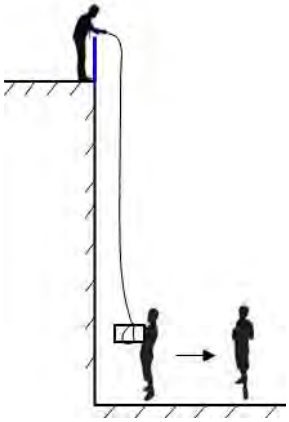


Fig. 8-7 Lifting up of Device

8.3.2 For Outdoor Duct

When the duct is located outdoors, the pipe to introduce the stack gas becomes cold due to the ambient air and the large amount of steam, which is included in the stack gas, freezes in the pipe. With no countermeasures taken, the pipe becomes clogged several minutes after the monitoring is started and no gas can pass through the pipe. This point requires the most attention in installation.

8.3.2.1 Configuration and Connection for Manual Operation Devices

1） Temperature Measuring Device

A thermocouple of the K type shall be used as the temperature sensor. There are two types of apparatus for displaying the temperature data (the portable temperature display or the logger). The logger not only displays the temperature but also records and stores the temperature every second.

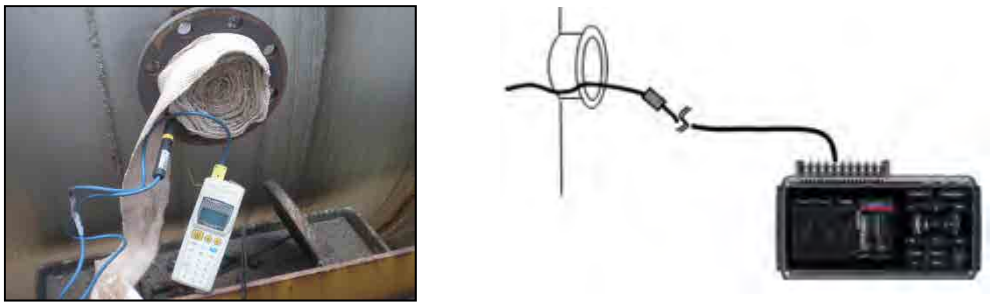


Fig. 8-8 Temperature Measuring Devices

The logger is often used because it can automatically record. The logger can accept other input signals (such as a measurement output of the stack gas analyzer) and, therefore, the logger shall be installed on the monitor side. When the distance is long between the stack side and the monitor side, the sides shall be connected using a long "dedicated temperature compensating conductor" (an ordinary signal line must not be used).

2） Gas Speed Measuring Device

The Pitot tube and a pressure gauge are used to measure the stack gas speed. A pressure gauge as a manual operation device is an inclined manometer.

Fig. 8-9 Gas Speed Measuring Device

The inclined manometer includes a liquid sealed therein and is used together with the liquid. In winter in Mongolia, the liquid must not freeze and, therefore, the liquid shall be ethyl-alcohol, which has a low freezing point (where available).

The Pitot tube and the inclined manometer are connected using two tubes and, when the distance is long between the stack side and the monitor side, the section in between may be connected by silicone hoses or Teflon tubes.

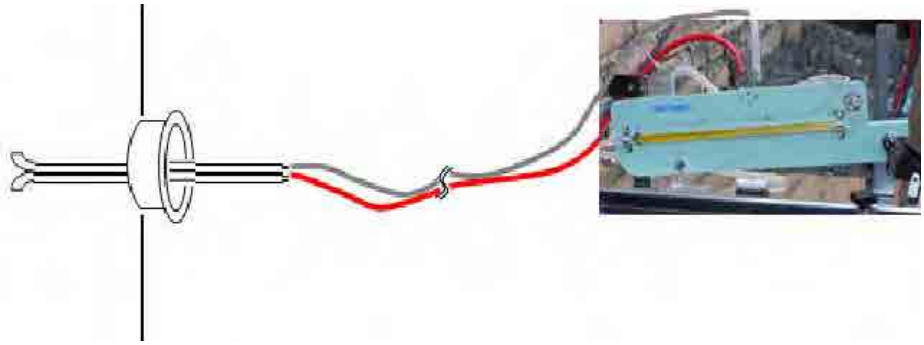


Fig. 8-10 Image of Installation of Gas Speed Measuring Devices

3） Moisture Sampling Devices

The stack-side devices consist of "the sampling tube, the Sheffield bottle, and a ribbon heater."

The monitor-side devices consist of "the trap, the suction pump (with a flow regulating cock), and the gas meter." The devices made in Japan include those that are driven at AC100V and it is necessary to use transformers to reduce the voltage from 220 V to 100 V.

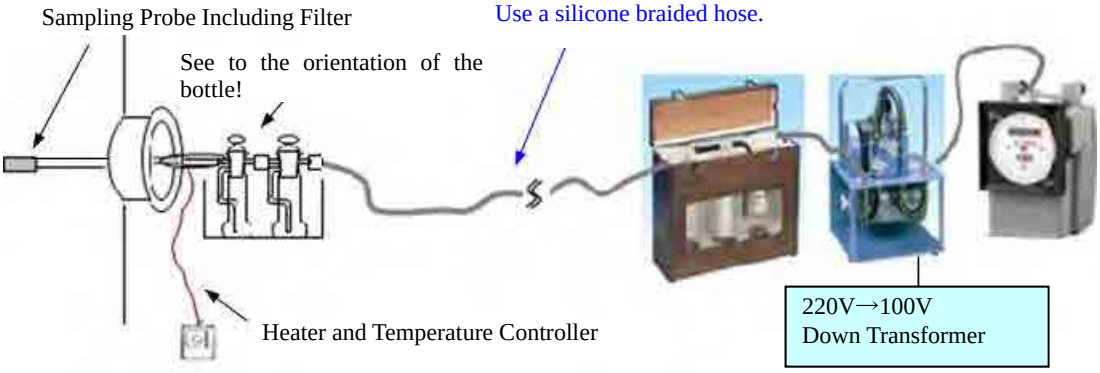
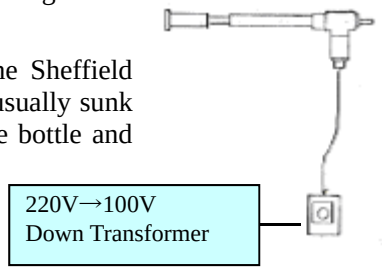


Fig. 8-11 Image of Installation of Moisture Sampling Devices

The Sheffield bottle is a tool for capturing only the steam in the stack gas. The sampling probe must be attached with a filter to avoid entry of dust in the stack gas into the Sheffield bottle. Because the ambient air is cold, the piping extending to the Sheffield bottle needs to be heated by a heater as shown in Fig. 8-7 (without the heating, the steam changes into water droplets, which do not enter the Sheffield bottle).

When the steam is adsorbed, the steam generates heat and the Sheffield bottle becomes hot. Therefore, the lower half of the bottle is usually sunk in the water tank (however, in winter, the atmosphere cools the bottle and the water tank is unnecessary).

A heating sampling probe as shown in the figure on the right may be used instead of "the sampling probe plus the ribbon heater."



4） Gas Component Measuring Devices (SO_2, NOx, CO, CO_2, and O_2）

The manual operation devices for measuring the gas components in the stack gas are roughly classified into the following two types:

① Wet Type Gas Sampling Set

See the Moisture Analysis Technical Manual. This book does not introduce this set because the measurement can be conducted only several times and the data is too poor to be used as representative data.

② Stack Gas Analyzer (Chemical Sensor Type)

The HOB often discharges CO gas whose concentration exceeds 1,000 ppm. Therefore, the sensitivity of the chemical-sensor stack gas analyzer is degraded due to the degradation of the sensor. For this reason, measurement of a high-concentration CO gas for a long time must be avoided. The measurement must be finished in a short time and it is necessary after obtaining one measured value to purge the line in the analyzer with the air in the room for a while.

To avoid the degradation of the sensor to the extent possible, the following measures shall be employed for the sampling (with this measuring method, the stack side and the monitor side are never connected to each other):

- Sample the stack gas in the gas bag using the twin balls. Sample the stack gas slowly taking five minutes for one bag (suction regularly to fill the bag such that the concentration of the sample in one bag after the sampling averages the gas concentration which fluctuates in five minutes).
- Analyze the concentration of the sample in the gas bag in a short time using the chemical-sensor stack gas analyzer and obtain one piece of data as a five-minute average value.

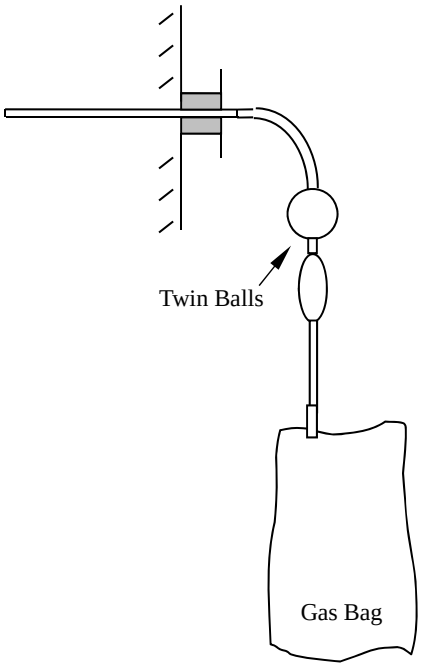


Fig. 8-12 Image of Installation of Gas Component Measuring Devices

The stack gas analyzer needs to be placed in a warm room (because its operation temperature is 0 to 40℃).

The measurement in this method only gives several pieces of data for one boiler and the data is poor as representative data similarly to that given by the Wet analysis method.

5） Dust Sampling Device

The stack side consists of "the dust sampling probe." The dust nozzle and the tube-type paper filter are set in the sampling probe.

The monitor side consists of "the trap, the suction pump (with the flow regulating valve), and the gas meter." The devices made in Japan include those that are driven at AC100V and it is necessary to use transformers to reduce the voltage from 220 V to 100 V.

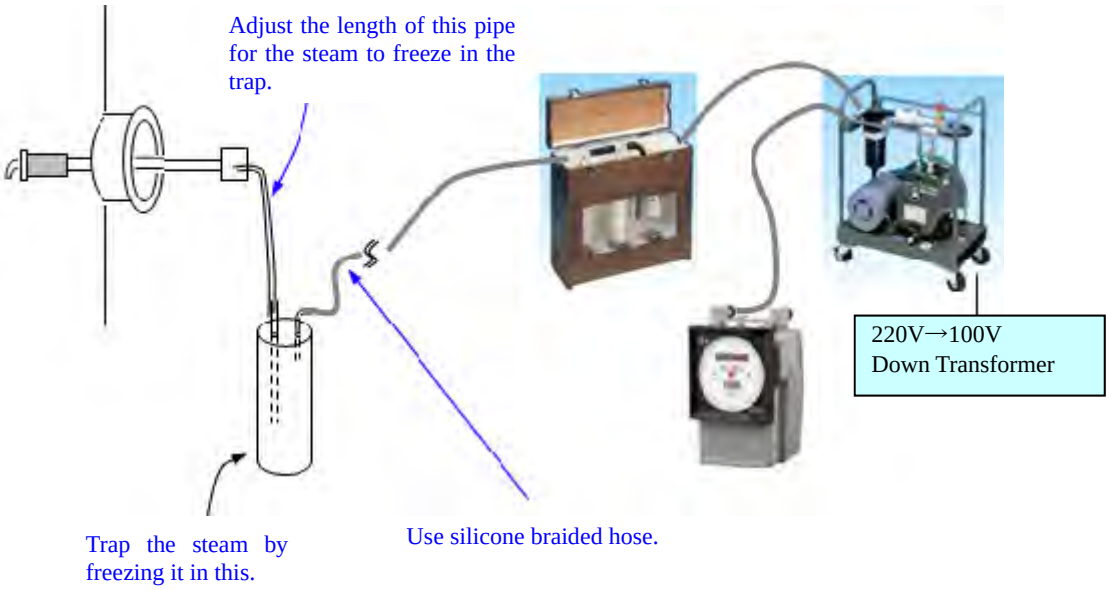


Fig. 8-13 Image of Installation of Dust Sampling Devices

8.3.2.2 Configuration and Connection for Automated Devices

As the configuration of the devices, the following items are different between the automated devices and the manual operation devices:

Table 8-4 Difference between Automated Devices and Manual Operation Devices

Name of Device	Difference between Automated Device and Manual Operation Device
Moisture Measuring Device	No difference. The same device is used for the manual measurement and the automated measurement.
Gas Component Measuring Device	Automated stack gas analyzer is used as the automated device.
Temperature Measuring Device	As the automated device, the automated dust sampler automatically measures both the temperature and the gas speed.
Gas Speed Measuring Device	
Dust Sampling Device	

An image of the installation of the automated devices is shown below.

1） Moisture Sampling Device

Same as that of the manual operation device.

2） Gas Component Measuring Device (SO_2, NOx, CO, CO_2, and O_2)

The stack gas analyzer (optical sensor type), which is robust against the influence of the interfering gases and can continuously measure, collects data of the concentration at a rate of a piece of data in 10 seconds (in the current setting).

The dust and the moisture in the stack gas must not enter the stack gas analyzer. As shown in the figure below, the parts for removing the dust and the moisture are inserted at various positions of the stack gas introducing line.

As to the coal boiler, the CO concentration sometimes becomes high that is in order of %. To precisely measure the concentration from a low concentration to a high concentration, prepare a stack gas analyzer for a low concentration and that for a high concentration and operate them in parallel to each other. According to the flow, suction the stack gas using a small pump and, thereafter, distribute the gas to input the gas into each of the measuring devices.

The devices made in Japan include those that are driven at AC100V and it is necessary to use transformers to reduce the voltage from 220 V to 100 V. It takes one hour to warm up the automated stack gas analyzer and, thereafter, it takes a further 30 minutes because the calibration must be conducted using the reference gas. To quickly conduct the measurement work, it is important to pre-warm the automated stack gas analyzers by installing these devices earlier than the other devices such as the dust samplers.

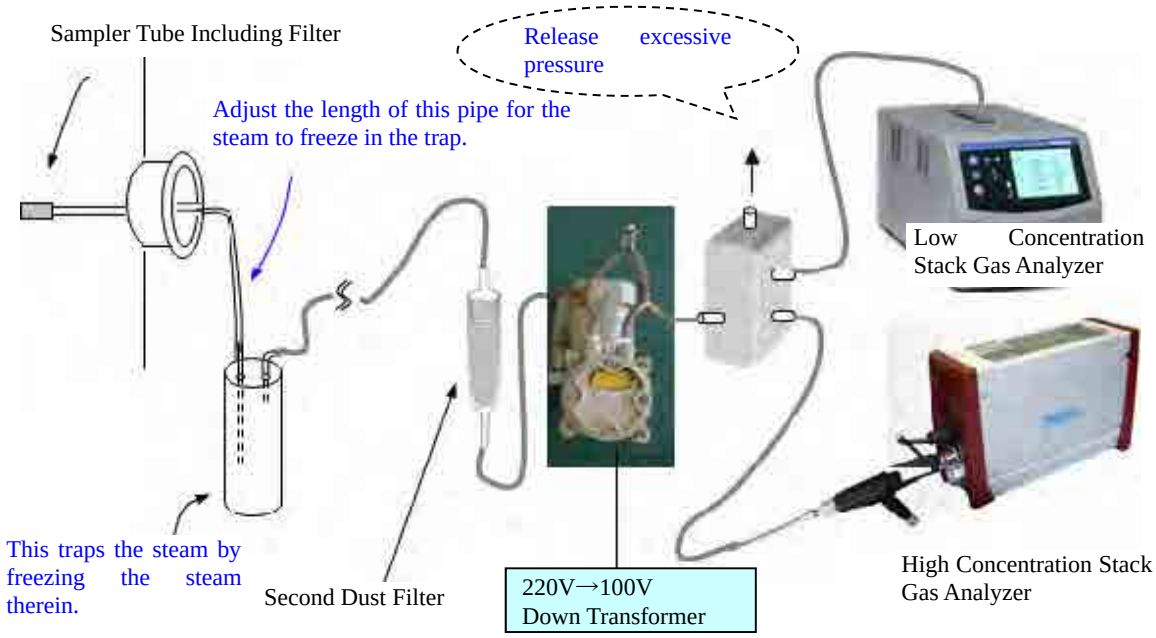


Fig. 8-14 Image of Installation of Automated Gas Component Measuring Devices

The data is automatically recorded into the logger by the low concentration stack gas analyzer and into an incorporated SD card by the device for the high concentration.

An uninterruptible power source shall be prepared for a power failure. This source can maintain the operation for several tens of minutes during a power failure.

3） Dust Sampling Devices

The stack side consists of "the dust sampling probe." The dust nozzle and a cylindrical filter are set in the sampling probe.

The monitor side consists of "the trap, the suction pump (with a flow regulating valve), the gas meter, and the sampling controller." The devices made in Japan include those that are driven at AC100V and it is necessary to use transformers to reduce the voltage from 220 V to 100 V.

Gas meters include wet-type gas meters and dry gas meters. When a wet-type gas meter is used, put antifreeze liquid in it.

See the technical manual for the piping and connection to the automated dust sampler.

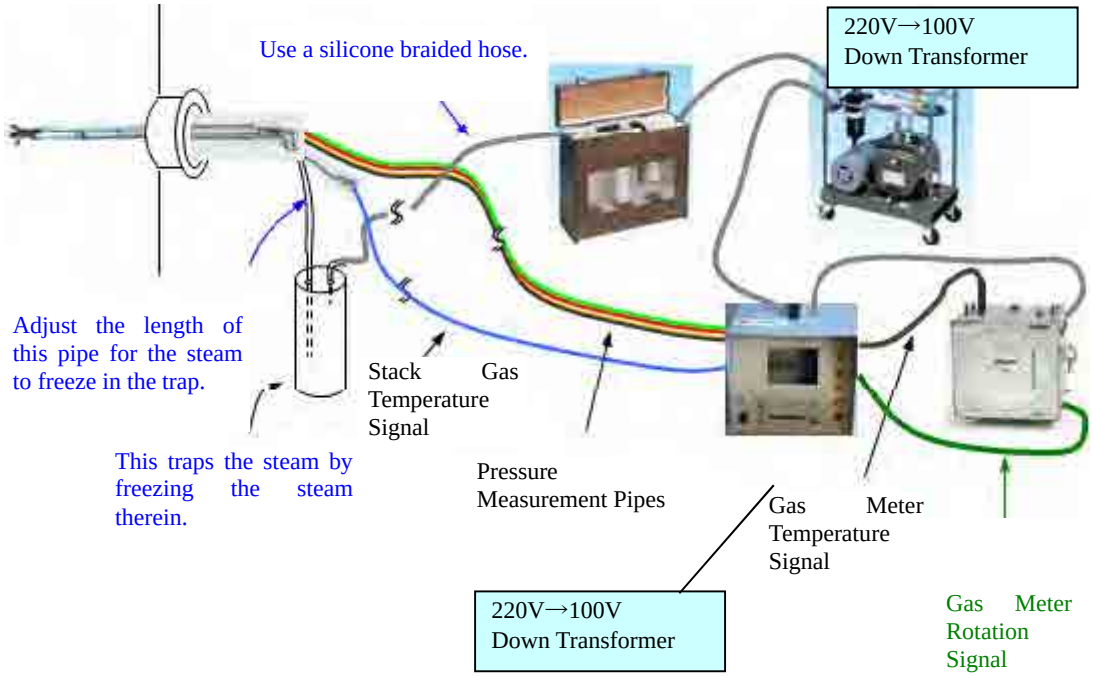


Fig. 8-15 Image of Installation of Automated Dust Sampling Devices

8.3.3 For an Indoor Duct

As to installation of the devices, the difference from 8.3.2 "For an Outdoor Duct" is that the length of wiring and the signal lines are shorter from the duct to the monitor side. In addition, when it is warm in the room, the "trap bottle" for trapping the steam does not need to be installed immediately after the sampling tube.

However, the floor of the room for the HOB is often cold due to the incoming cold atmosphere from the outside and, therefore, the steam in the stack gas becomes water in the piping and runs on the floor.

As to the dust sampling devices, the steam changes to water in the pipe and, thereafter, the water is captured by the trap box and causes no problem. However, in the automated gas component measurement line, it is necessary to introduce a measure to avoid any water from entering the automated measuring device by, for example, inserting a trap bottle as shown in the figure below.

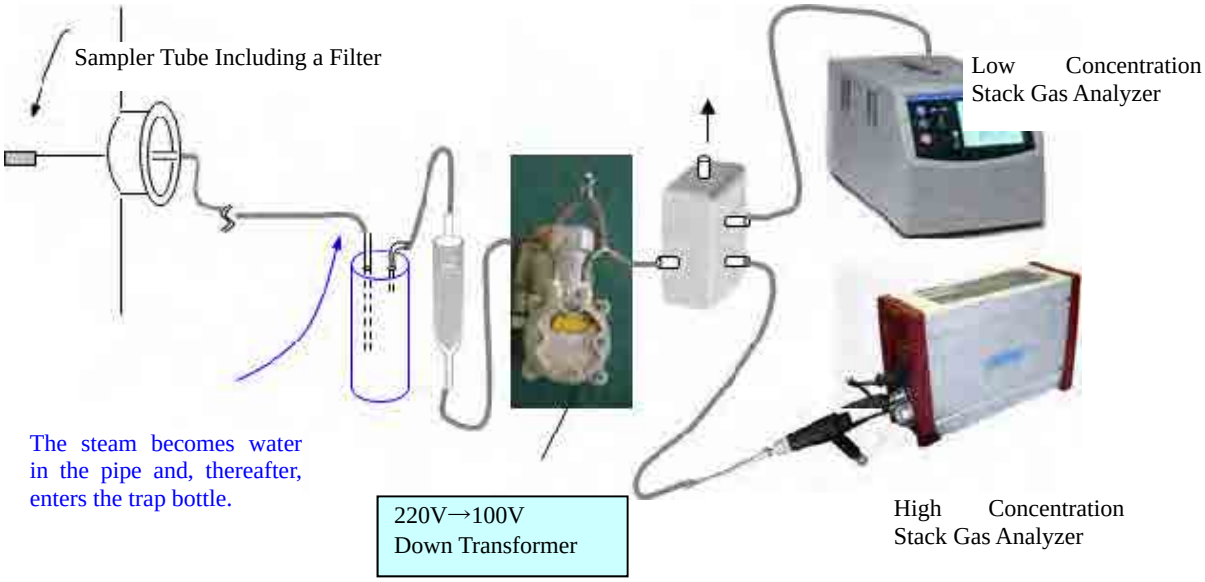


Fig. 8-16 Image of Installation of Gas Component Measuring Devices (in Warm Room)

An uninterruptible power source shall be prepared for a power failure. This source can maintain the operation for several tens of minutes during a power failure.

8.4 Checks after Installation

8.4.1 Checks on Operation

The following checks shall be conducted to check whether the main devices operate normally:

Table 8-5 Items to Be Checked after Warming up

Name of Device	Item to Be Checked
Suction Pump	Start up the oil pump immediately while the pump is warm after it is installed. When the room is cold, heat the oil tank. Once the pump is turned on, keep the pump rotating (because, when the room is cold, it is difficult to turn ON the pump again once the pump is turned OFF).
Gas Meter	When the pump is connected to the gas meter and is turned on, check that the gauge of the gas meter rotates round and round.
PC	The PC does not work well when the room is cold. Warm the PC properly using an electric blanket.
Stack Gas Analyzer	Turn ON this analyzer immediately after its installation (because it takes one hour to warm up the analyzer). Put the analyzer in the state for suctioning the room atmosphere. Connect the analyzer to the logger. (Conduct the operations following the technical manual.) If the stack gas analyzer is placed in the vehicle, the stack gas suctioned by the analyzer fills the inside of the vehicle and harms the health of the members. The stack gas may be discharged out of the vehicle by connecting a pipe to the outlet of the analyzer. However, when the pipe is thin and long, it influences the measured value and, therefore, the pipe must be thick and short.
Logger	Set the USB memory and check that the following input signals are sent: ・The measured values of the five items of PG-250 (SO_2, NOx, CO, CO_2, and O_2) ・The measured value of the stack gas temperature sensor (Conduct the operations following the technical manual.)
Inclined Manometer (Manual Operation Device)	Set the inclination to be 1/20. With the differential pressure that is zero, check that the liquid level of the included liquid (ethyl alcohol) is zero to 5 cm on the scale. If the liquid is insufficient, replenish the tank with liquid. When this zero position is checked, take care to avoid any wind entering from the two inlets.
Automated Dust Sampler	After turning this sampler ON, check the display on the screen. Check that there is sufficient printer paper. Conduct zero adjustment with the differential pressure that is zero.

8.4.2 Leak Check on Pipes

As described in Item 8.3, the devices are connected to each other using many joint pipes. If a joint pipe is decoupled or has a hole, normal measurement cannot be conducted because the room atmosphere enters through the decoupled portion or the hole.

After connecting the pipes, the pipes must be checked to confirm that no leakage exists, according to the following method:

8.4.2.1 Moisture Line and Dust Line

Conduct the leak check according to the following procedure:

① Operate the pump (an arbitrary speed may be employed).

② Check that the gauge of the gas meter rotates (adjust the rotation speed to a proper speed using the flow regulating valve of the pump).

③ Pull out the end of the pipe on the stack side from the sampling probe and close the tip of the tube using a finger.

④ Observe the gauge of the gas meter. When no leak exists in the pipe, the rotation gradually slows and finally stops.

⑤ If the rotation does not stop, take off the pipe joint starting with the pipe joint closer to the pump and repeat the checks in ③④. Find the position of the leakage and repair the leakage.

The suction flow of the dust sampling pump is large and the rotation of the gauge usually stops shortly after the pump starts suctioning. In contrast, the flow of the moisture pump is relatively small and, therefore, it takes time to remove the air from the pipe. Therefore, be prepared to wait longer than estimated. Somewhat increasing the flow using the regulating valve results in a shorter time to suction the air.

However, when the trap bottle is a plastic bottle, the bottle is gradually crushed as the inside of the pipe becomes a vacuum. It is better to check the leak without the trap bottle not to break the trap bottle. To check the leakage of only the trap bottle, suck on the bottle.

It is necessary to take care when the leak check is conducted on the automated dust sampling devices. This leak check is described in 10.22.

Fig. 8-17 Leak Check on Pipes

8.4.2.2 Line for Gas Components

Install the gas meter downstream of the suction pump and conduct checks according to the same method as that described in 8.4.1.

8.4.3 Measurement of Duct Diameter and Flange Length, and Calculation of Measurement Points

For the gas speed measurement and the dust sampling, calculation must be conducted to determine at which point the stack gas and the dust are collected in the cross section of the duct for each facility. The figure of the image below shows the case where the cross sectional shape of the duct is a rectangle.

As the gas speed differs depending on the position in the duct, in order to obtain a representative value as one duct, plural measurement points are usually provided in the cross section of the duct. The measurement points are increased as the size of duct becomes larger. See the technical manual for the method of calculating the positions of the sampling points (the black points in Fig. 8-14 below).

When the dust sampling probe and the Pitot tubes are inserted into the duct, adjust the length of the insertion of the probes such that the ends of these probes are placed at these positions.

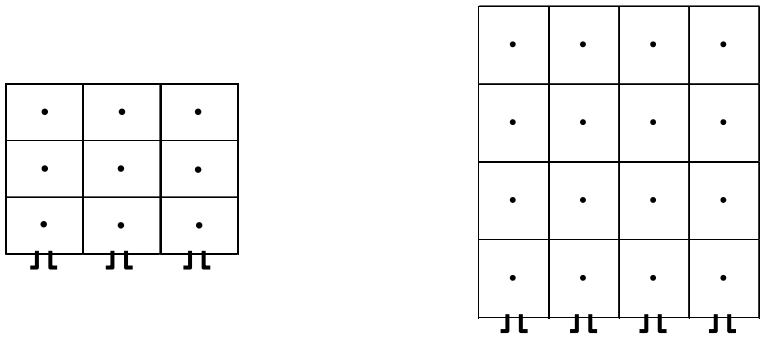


Fig. 8-18 Positions of Measurement Points in Cross Section of Duct (for Rectangular Duct)

Go to the measurement hole and wear a mask and protective goggles, and wear the safety belt if works at high place. Take care not to fall or drop anything.

Take off the lid by rewinding the bolt screws in the flange portion. There are cases where the pressure in the duct is higher or lower than the atmospheric pressure. When the pressure in the duct is higher, the stack gas may blast out into the face when the lid is taken off. Therefore, take care when the lid is taken off. For measurement holes that have not been used for a long time, dust accumulates on the flange. In an extreme case, the dust closes the hole. Remove the dust using pipes, etc., and clean the hole.

Measure the size of the inner diameter of the duct using a relatively long pipe. Measure the size by inserting the pipe deep into the hole as shown in the photos below. Measure the length of the flange. Based on these measured values, calculate the positions of the measurement points by manual calculation according to the technical manual and record the results in the recording paper sheet.

Fig. 8-19 Opening of the Measurement Hole and Cleaning Thereof

Fig. 8-20 Measurement of Size of Measurement Hole

8.4.4 Start-up of PC, Preparation of Calculation Sheet, etc.

Start up the notebook PC and open the Excel calculation sheet dedicated to the stack gas measurement. Input all of the information obtained in the interview with the boiler operators, the measurement results of the duct size, etc.

Measure the atmospheric pressure and input the result into the calculation sheet.

9. On-site Measurement Work 1 (For Manual Operation Equipment)

As shown in 6.1.1, preliminary measurement is required for stack gas measurement with manual operation equipment before dust sampling. A lot of data obtained through this preliminary measurement will be used for calculations to determine the control conditions of the manual type dust sampler for smooth dust sampling after the preliminary measurement.

9.1 Preliminary Measurement

After installing necessary equipment on the stack side and the monitor side after confirming they operate normally, start measurement of the temperature, flow speed and moisture step by step.

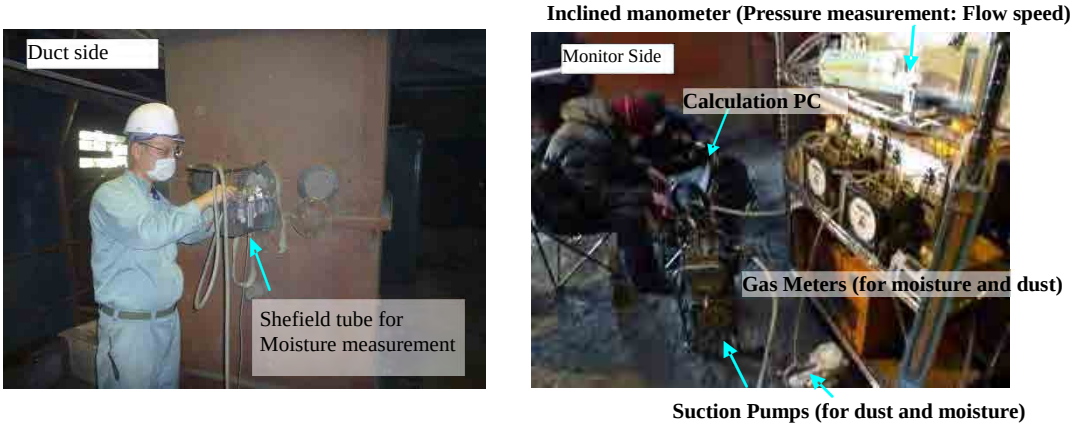


Figure 9-1 Measurement at the HOB Site

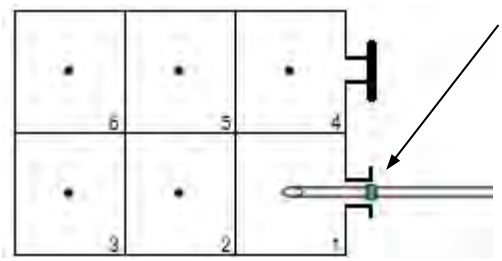
9.1.1 Measurement of the Temperature (Common to Manual and Automatic Equipment)

Measure the flue gas temperature in the duct with the equipment specified in 8.3.1.1. After observing the condition around one minute, read an approximate average value and write it down on the record sheet. The head of the Type K thermocouple may be located in any place inside the duct. However, take care for the tip not to be contact with the internal wall of the duct.

9.1.2 Measurement of the Flow speed (Manual)

The theory of flow speed measurement is specified in the technical manual.

The following is a conceptual illustration for measurement of the flow rate at the six points in total in the duct. The tip of the Pitot tube is placed at the first point to measure the flow speed.



Insert the Pitot tube properly so that its tip may be located exactly at the first measuring point.
For this purpose, provide a tape marker at this position of the Pitot tube so that one can discern it when viewed from outside.
This position as a place of enrolling a adhesive tape should be determined beforehand, as calculated at 8.4.3.
The second point and subsequent points also are marked with adhesive tape as position reference.

Figure 9-2 Positions of the Pitot Tube for Measurement of the Flow Rate

At the tip of the Pitot tube, there are two apertures: the one facing to the flow of flue gas is

called the total pressure aperture, while the other is called the static pressure aperture. The total pressure aperture must be directed squarely to the flow of flue gas (the angular tolerance is ±5°).

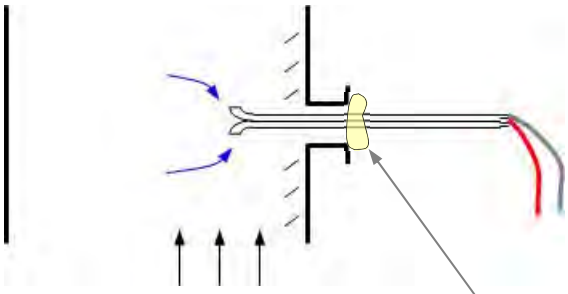


Figure 9-3 Measurement of the Flow Rate (Side View)

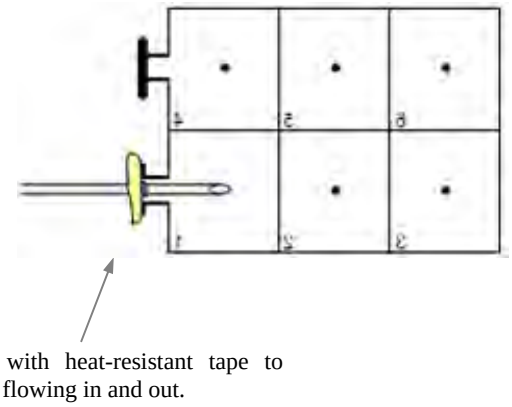


Figure 9-4 Measurement of the Flow Rate (Sectional View)

Measure the flow speed, following the procedure below. Write down the angle of the manometer (such as 1/20) and the pressure value measured at each point (marked on the scale of the inclined manometer) on the record sheet.

(1) Read the zero point of the inclined manometer.

Before inserting the Pitot tube into the duct, put the tip of the Pitot tube into a bag (to prevent it from being affected by a wind), and check the reading under the condition that the same atmospheric pressure is applied to the two apertures. That is, read the scale without differential pressure.

(2) Read the dynamic pressure value (Pa) and the static pressure value (kPa) at the first measuring point.

In the Figures 9-3 and 9-5, a red tube is used for connection to the total pressure side, while a grey tube is used for the static pressure side. Insert the Pitot tube slowly into the duct, and set it in the measuring position.

Figure 9-5 Inclined manometer

At this time, the level of ethyl alcohol becomes turbulent due to a shock caused by a large difference

between the pressure in duct and the atmospheric pressure, if any. When the difference is too large, the ethyl alcohol flies out to the glass bulb, overflowing the right edge of the scale. In this case, when introducing the Pitot tube, as a preparatory step, the red and grey tubes are pinched by hand not to produce a sharp shock. Keeping this state, set the Pitot tube just at the first reference point. Then, gradually open the plied tubes so that pressure may work on gently the inclined manometer. Not agitating the level of liquid is the cue to get a correct reading.

The value read here is equivalent to a dynamic pressure.

Then, detach the red tube (the total pressure side shown in the Figure 9-5) from the inclined manometer, and read the scale. The read value is equivalent to a static pressure. Depending on the boiler, the static pressure in duct may become positive or negative. The magnitude of pressure also differs according to the boiler.

When measuring a large positive or negative static pressure, set the angle of the inclined manometer at 1/10, 1/5, 1/3 or vertically. When the pressure is too large to measure with these inclinations, measure the value with the U-tube filled with water.

In this inclined manometer, the graduation of 10 is equivalent to 1,000Pa at the inclination of 1/10. Since the reading method used for this system is different from those in conventional products in which readings are given in millimeters, be careful not to make mistakes.

(3) Read dynamic and static pressure values at the other measuring points in the same manner as in (2).

Figure 9-6 Measurement of Flow speed

9.1.3 Measurement of Moisture Contents (Common to Manual and Automatic Equipment)

It is possible to determine the moisture concentration of the flue gas referring to the fact that the desiccant of CaCl2 included in a Shefield bottle increases its weight when absorbing the water. For details, refer to the technical manual. The measurement procedure is as follows.

(1) Take six Shefield bottles prepared for this purpose out of the storage box.

(2) Prepare an electric balance in conditioning. Place it on a flat surface inside the warm room and set it in correct regulation of level. Set the balance not to be affected by the wind.

(3) Make a zero setting for the electric balance.

(4) Weighing of Shefield bottles before use

Close the cock, and weigh each bottle. Before the measurement, completely remove any dirt and/or water adhering to the surface of the bottle with clean tissue paper.

Write down the original pre-measurement weight on the record sheet (together with the bottle

number).

Figure 9-7 Weighing of the Shefield Bottles Before Use

(5) Then, connect two Shefield bottles with a silicon tube in order to store them as a set (three sets in total). When the connecting silicon tube is too long, there is a adverse possibility that the water may accumulate at the joint. When the connection tube is too short, it is easily detached. Connect the two bottles by using a tube of a proper length to reduce the connecting distance as much as possible.

(6) Installation of the Shefield Bottles

The figure below is the same as the Figure 8-11.

Set a set of Shefield bottles with their cocks closed at the measurement aperture paying attention to the direction of the bottles. Seal the clearance with heat-resistant tape.

Set a ribbon heater as closely as possible to the inlet of the bottle as shown in the figure, in order not to allow the vapor to turn to water under the effect of cold atmospheric air, before entering the bottle. Do not raise the temperature of the ribbon heater too much (the silicon tube may be burnt at an excessively high temperature).

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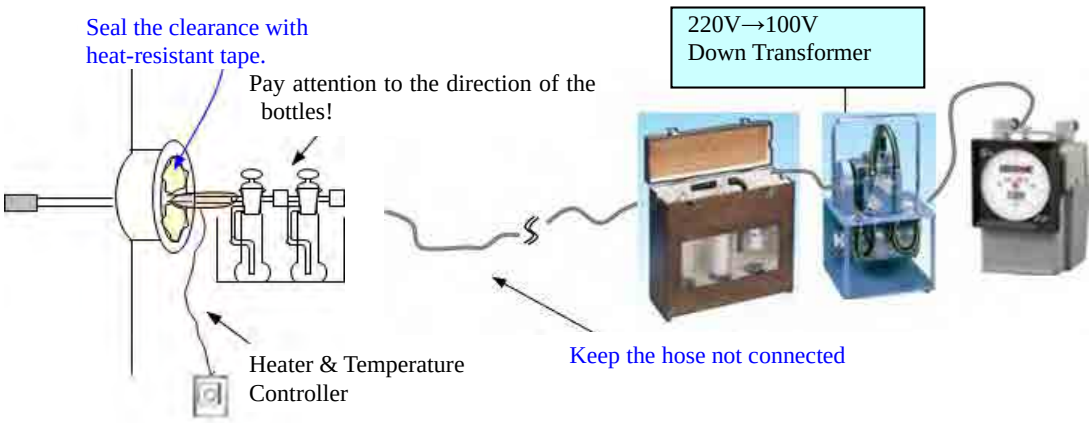


Figure 9-8 Sampling of Moistures

(7) Immediately before Starting Sampling

Before starting sampling, adjust the flow rate of the pump to approximately 1L/min. After stopping the pump, read the accumulated flow rate of the gas meter, and write it down on the record sheet as the read value before sampling. Confirm the bottle numbers of the set Shefield bottles.

(8) Timing of the Sampling

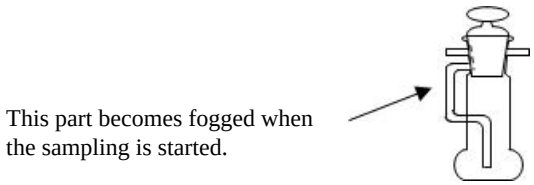
For collection of three sets of moisture samples in total, decide when to start sampling and when to finish appropriately, depending on the operating status of the boiler.

Usually, it takes five minutes for one set at a flow rate of approximately 1L/min, but the concentration of the coal boiler flue gas largely changes, depending on the operating condition of the boiler. To obtain a representative average, the length of time, timing and suction speed for sampling may be changed. Refer to the "Stack Gas Measurement Protocol."

(9) Start of the Sampling

Before starting the sampling, attach the detached hose. Open the two cocks of the Shefield bottles by turning them to the open side (be careful to turn them to the right direction). Soon after the communication between the stack side and the monitor side, turn on the pump and start sampling. Use a walky-talky for smooth communication between the two sides, when needed.

When the sampling is started, water vapor goes into the bent tube of the Shefield bottle, making the inside of the tube fogged. Be sure to confirm this phenomenon.



Measure the rotation time of the gas meter, and confirm that the suction rate is around 1L/min (the rate may be lower than this for a longer suction time).

(10) During the Sampling

Confirm that the sampling is going on smoothly with water drops adhering to the inside of the Shefield bottle. In addition, check that water vapor does not become water before going into the bottle due to the misalignment of the ribbon heater wrapped around the tube. If the heater is misaligned, wrap it properly. Read the temperature of the gas meter, and write it down on the record sheet. Check the rotational speed of the gas meter from time to time in order to confirm that the rate does not decline (if it has declined, clogging or leakage may be caused).

(11) End of the Sampling

Stop the pump when the scheduled closing time comes. Close the cocks of the Shefield bottles, and remove the first set of bottles for recovery. Take the reading of the gas meter, and write it down on the record sheet as the post-sampling value.

(12) Post-weighing of the Shefield Bottles

Completely remove any dust and/or moisture on the surface of the first set of recovered bottles with tissue paper. Then, weigh it with the electric balance, and write down its weight on the record sheet.

(13) Moisture Sampling for the Second and Third Sets

After finishing the sampling with the first set at (11), repeat the above steps from (6) through (12) to collect data with the second and third sets. Calculate the moisture concentration by using a dedicated dust calculation software. When the reading taken is found abnormal, an additional measurement is required with the fourth set.

9.1.4. Measurement of the Gas Component

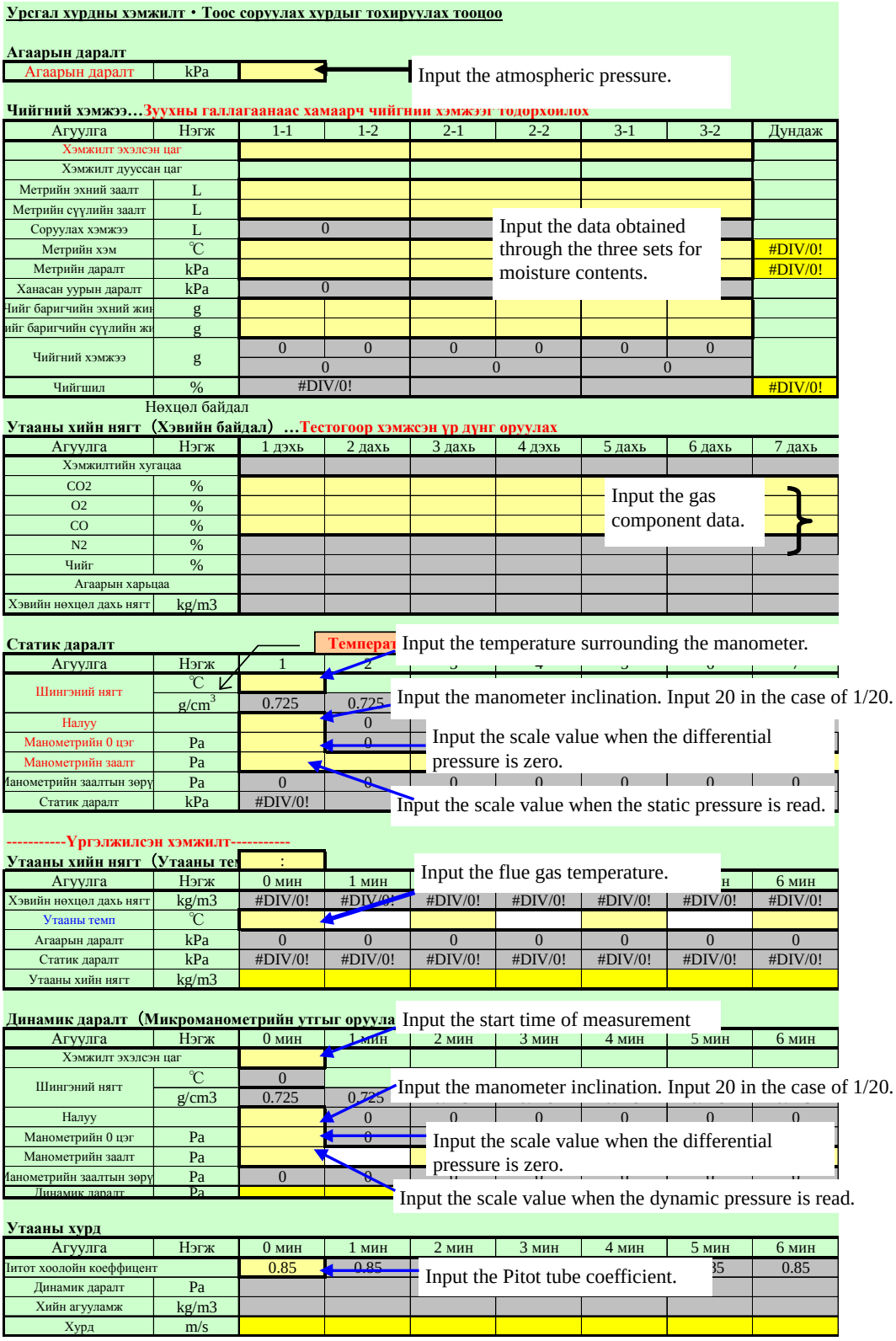
When a chemical sensor-type stack gas analyzer is used, conduct measurement, following the sampling method and procedure specified in 4) of 8.3.2.1. Collect the samples as many as possible for better results. Be sure to collect the data on the gases if high concentrations come out after coal is fed into the boiler.

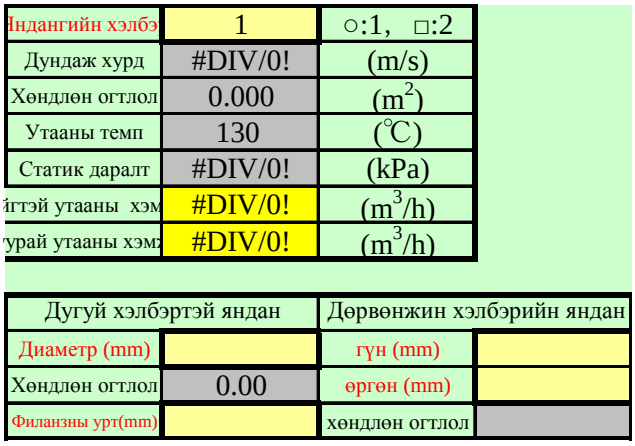
The concentration peak comes differently in time according to the measurement item. Pay attention

to the sampling timing.

9.1.5 Input to the Dedicated Dust Calculation Software (Manual)

Input the data collected from 9.1.1 through 9.1.4 to the dedicated dust calculation software.





Индангийн хэлбэ	1	○:1, □:2
Дундаж хурд	#DIV/0!	(m/s)
Хөндлөн огтлол	0.000	(m^2)
Утааны темп	130	(℃)
Статик даралт	#DIV/0!	(kPa)
йгтэй утааны хэм	#DIV/0!	(m^3/h)
урай утааны хэм	#DIV/0!	(m^3/h)

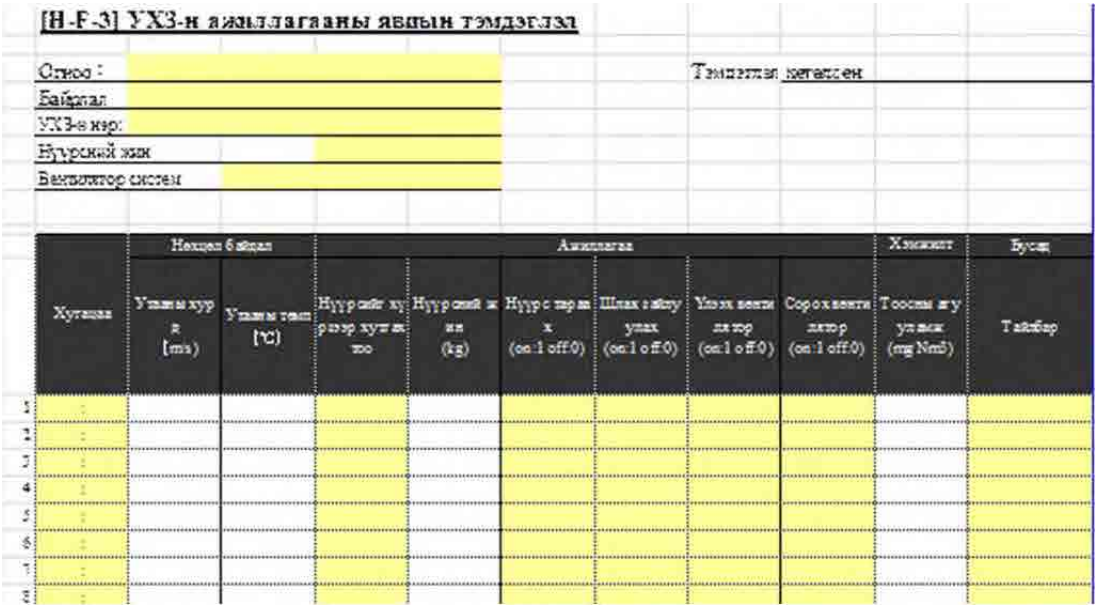
Дугуй хэлбэртэй яндан		Дөрвөнжин хэлбэрийн яндан	
Диаметр (mm)		гүн (mm)	
Хөндлөн огтлол	0.00	өргөн (mm)	
Филанзны урт(mm)		хөндлөн огтлол	

Input the data on the stack shape & size and the flange size.

Figure 9-9 Dedicated Dust Calculation Software (For Manual Equipment)

9.2 Recording of the Fed Coals and the Operations of the Boiler

The combustion condition of furnace in coal thermal power plant is much more stable than that of HOB operation, the concentration fluctuation of flue gas is generally stable as well. The operation condition record sheet, in which the control staff fills the data, will give enough hourly information for thermal power plant, while detailed operating record is required for HOB measurement where unstable burning condition is expected. Needless to say, keep the record, once trouble happened on the operation of the target boiler.



[Н-Ғ-3] УХЗ-н ажиллагааны явцын тэмдэглэл

Огноо :

Байрлал

УХЗ-н нэр:

Нүүрсний нэр

Вентилятор систем

Тэмдэглэл хөтөлсөн

Хугацаа	Нэгдсэн блокийн		Ангилагч						Хяналт	Бусад
	Утааны хурд (m/s)	Утааны темп (℃)	Нүүрсийг хуурай хутгах тоо	Нүүрсний нэрэх (kg)	Нүүрс нэрэх (on:1 off:0)	Шлак гайгуулах (on:1 off:0)	Үлээх вентилятор (on:1 off:0)	Сорох вентилятор (on:1 off:0)	Тоосны агуулах (mg/Nm3)	Тайлбар
1										
2										
3										
4										
5										
6										
7										
8										

Figure 9-10 Boiler Operation Recording Sheet

9.3 Dust Sampling (Manual)

Capture the dust on the cylindrical filter, and determine the weight of the captured dust by using the difference between the weight of the cylindrical before sampling and after sampling. This is a method of obtaining a dust concentration from the total volume of gases sampled which are determined by a gas meter. Adopt the isokinetic sampling method enables to capture the dust particles as precisely as possible. For details of the approach, refer to the technical manual.

Follow the procedure below:

(1) Calculate the isokinetic sampling speed with the dedicated dust calculation software.

Open the sheet recording the inputted preliminary measurement results in Section 9.1. For calculation of an isokinetic suction speed, it is necessary to determine the inner diameter of the nozzle attached to the sampling probe first. There are a total of nine nozzles (inner diameters: 4, 6, 8, 10, 12, 14, 16, 18 and 20mm) in the nozzle box.

Figure 9-11 Dust Sampling Nozzles and Filter Holder

The size of nozzle to be used is determined based on the following conditions.

Table 9-1 How to Choose a Dust Sampling Nozzle

No.	Requirements for selection of a nozzle
1	The isokinetic sampling speed is calculated after inputting the selected nozzle inner diameter into the dedicated dust calculation software. This speed must not exceed approximately 25L/min.
2	Choose the nozzle with the largest diameter, satisfying the above.
3	It is acceptable to choose the nozzle with a smaller diameter than that of Item 2 when the sampling time will be extended due to an expected lower dust concentration.

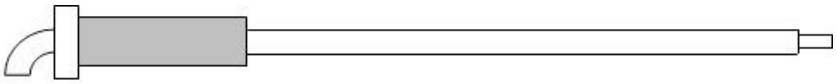
Агуулга	Нэгж	0 мин
Хошууны диаметр	mm	16
Хийн урсгал хурд	m/s	2.71
Чийгний хэмжээ	%	9.84
Метрийн темп	℃	7
Утааны темп	℃	128
Агаарын даралт	kPa	87.7
Статик даралт	kPa	0.001
Метрийн даралт	kPa	0.04
Ханасан уурын даралт	kPa	0
Соруулах хэмжээ	L/min	20.57
Соруулах хурд	sec/L	2.92

According to the above table, the nozzle of 16mm is selected with a calculated suction flow

rate of 20.57L/min.

(2) Take out a new cylindrical filter having a smaller number from the storage case containing filter paper cylinders already weighed, and fix it to the holder. Make adjustment so that the bottom of the filter paper does not contact with the filter holder bottom. Attach the nozzle with a selected inner diameter.

Make sure to place the packing, and tighten the nozzle with the cover ring. Connect the pipe (properly wind sealing tape to prevent leakage).



The following is a conceptual illustration for measurement of the flow rate at the six points in the duct. The tip of the sampling probe is placed at the first point to take the dust sample (the same image as that of the Pitot tube). Mark the sampling positions on the tube with tape.

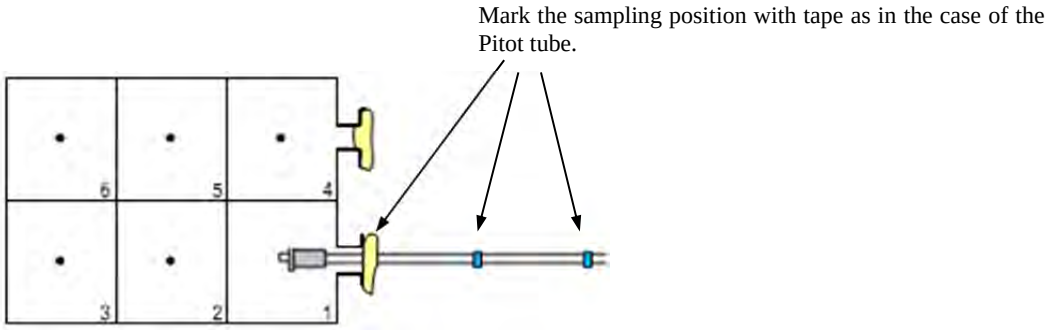


Figure 9-12 Inserting Position of the Sampling Tube with Marking

(3) Setting of the Sampling Tube

Insert the sampling probe prepared in 9.3 into the duct. As the figure below shows, the sampling probe is placed horizontally when the stack is vertical. The sampling nozzle is directed upward until the dust sampling starts. Seal the clearance with heat-resistant tape.

Insert the Pitot tube and the Type K thermocouple together with the sampling probe. Pay attention to where to set them so that they do not interfere with one another to disturb the flow. When the stack is vertical as shown in the figure, the dust sampling probe and the Pitot tube should be set side by side horizontally to prevent disturbance when the stack is placed vertically.

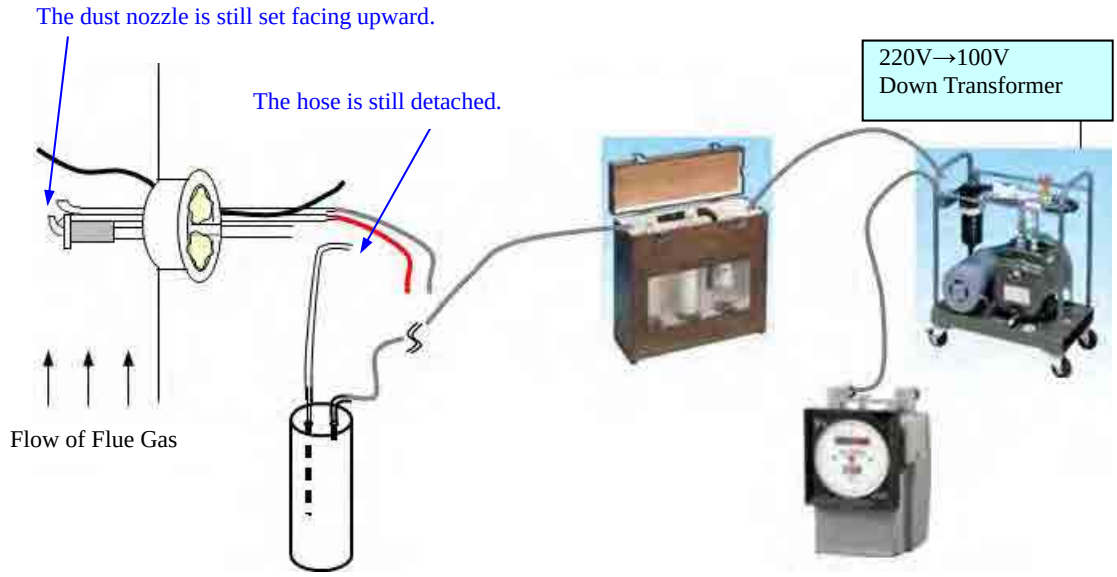


Figure 9-13 Before Dust Sampling

(4) Immediately Before Sampling

Turn on the suction pump temporarily. Adjust the flow control valve of the pump to set the suction flow rate to approximately a calculated value by measuring the rotation of the gas meter. After the adjustment, stop the suction pump. Read the accumulated flow rate of the gas meter, and write it down on the record sheet as the value read before sampling together with the number of the set filter paper cylinder.

(5) Timing of the Sampling

Although a total of three dust samples or more will be collected, the start time and the end time must be decided properly, depending on the operating status of the boiler.

The concentration of the coal boiler flue gas significantly changes, depending on the operating condition of the boiler. To obtain a representative average, give consideration to the timing of when to conduct sampling. Refer to the “Stack Gas Measurement Protocol.”

(6) Start of the Sampling

Before starting the sampling, connect the hose which has been kept separated. Turn the nozzle properly to be faced with the flow of the flue gas (the angular tolerance is ±5°). Determine the insertion position of the sampling probe in accordance with the tape marked on the sampling probe so that the sampling nozzle is properly located at the measuring point.

Establish the necessary lines for the Pitot tube and the temperature sensor.

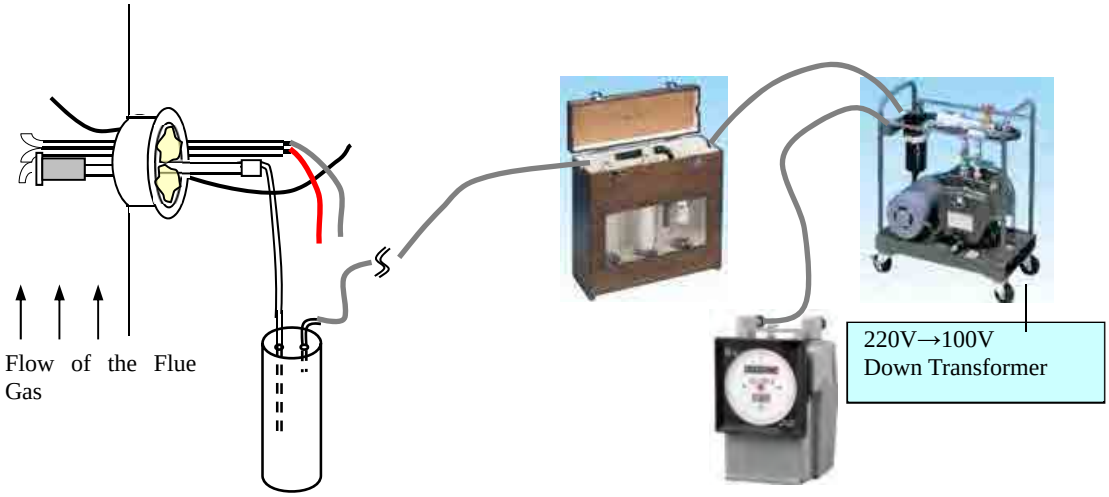


Figure 9-14 Start of the Dust Sampling

Turn on the suction pump to start sampling. Use the walky-talky for smooth communication, when needed.

After start, immediately conduct the following flow rate adjustment operations.

Table 9-2 Procedure for Adjustment of the Suction Flow Rate in Dust Sampling (Isokinetic Suction Control)

No.	Suction Flow Rate Adjustment Procedure
1	Read the current flue gas temperature with the logger, and input it into the dedicated dust calculation software (also on the record sheet).
2	Read the current dynamic pressure with the inclined manometer, and input it into the dedicated dust calculation software (also on the record sheet).
3	Read the temperature and the pressure of the gas meter, and input them into the dedicated dust calculation software (also on the record sheet).
4	Readjust the flow rate control valve again to make the flow rate close to the value automatically calculated with the dedicated dust calculation software.

(7) During the Sampling

Repeat the flow rate adjustment procedure shown in Table 9-2 at an interval of one minutes to maintain the isokinetic suction conditions. It is necessary to repeat the adjustment minutely since the suction rate declines as the cylindrical filter clogs with dust.

Check that the sampling probe is set horizontal correctly at its insertion position.

Confirm that water vapor is frozen inside the trap bottle. If it is frozen inside the piping upstream or downstream from the trap bottle, the piping is clogged and the suction pump

does not work properly (the rotation of the gas meter becomes extraordinarily slow). When any clogging is found, stop the sampling temporarily to replace the clogged piping, adjust and correct the piping length before the trap bottle. Then, start the sampling again.

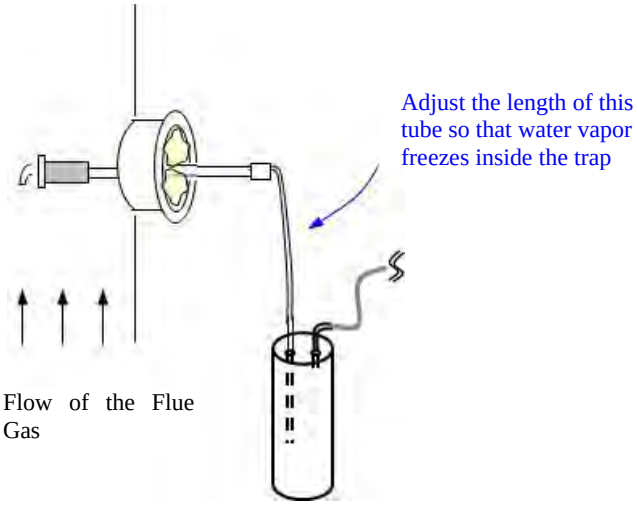


Figure 9-15 How to Fix the Tube Clogged with Freezing

(8) End of the Sampling

As a rule, conduct the flue gas sampling for 20 minutes per cylindrical filter. When the sampling time is extended further, be careful not to cause clogging in the cylindrical filter (stop sampling immediately when any clogging sign is seen).

Stop the suction pump when the sampling time ends. Pull the sampling probe out of the duct, and collect the cylindrical filter (Photo: Dedicated collecting bottle set). Read the scale of the gas meter, and write it down on the record sheet as the post-sampling value.

Figure 9-16 Collecting Filters after the Sampling

(9) Dust Collection for the Second and Third Sets

After completing the sampling at the first measuring point in (8), repeat the above steps from (1) through (8) for the sampling at the other measuring points. Collect three or more filter paper cylinders per boiler.

(10) Moving Sampling Method

The above procedure is the basic approach where one cylindrical filter is used at each measuring point. It is possible to conduct sampling at all measuring points with a single cylinder.

For example, after the ten-minute sampling at the first measuring point, displace and set the probe to the position to the second point, keeping the same cylindrical filter, and conduct another 10-minute sampling. The same 10-minute sampling process is repeated at the third and fourth points with the same filter. This is called the moving sampling method.

Needless to say, the suction flow rate must be adjusted minutely considering the flow speed differs according to each point.

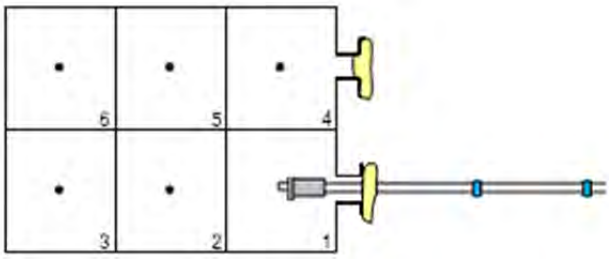


Figure 9-17 Sampling Tube and Measuring Points

However, the sampling must not be ended with the single cylinder even when using the moving sampling method. Be sure to collect at least three cylindrical filter samples per duct.

10. On-site Measuring Work 2 (with Automated Equipment)

For the use of the automated equipment, it is unnecessary to conduct a preliminary measurement required for the manual equipment as shown in the process of the Figure 6-2. Immediately after installing the necessary equipment and observing the flue gas temperature and the flow speed for a short time, you can start an automatic measurement.
The automated dust sampler has a Type K thermocouple and a Pitot tube, which are attached to its sampling probe. Its design allows to collect necessary data such as the temperature and pressure (flow speed) of the flue gas while sampling dust.
The continuous stack gas analyzer shown in 8.3.2.2 and 8.3.3 collects the gas component data. The moisture data is collected in the same manner as the manual equipment. However, the moisture sampling is conducted simultaneously with the dust sampling.

10.1 Measurement of the Gas Component (Automatic)

As specified in 2) of 8.3.2.2, the continuous stack gas analyzer must be installed and started earlier than other equipment. After warming-up the analyzer, make calibration using standard gases.

10.1.1 Calibration of the Continuous Stack Gas Analyzer

Calibration is a must to be conducted prior to the measurement with the stack gas analyzer on the day of a measurement.
After warming up the stack gas analyzer and confirming its normal operation, start collecting the necessary data with the logger.
Connect the cylinder filled with the standard gas to the standard gas inlet of the stack gas analyzer, and introduce the standard gas flow into the analyzer with the specified pressure. Adjust the sensitivity for each measurement item.

In the case of gas analyzers made in Japan, they differ from one another about how to introduce the gas into the analyzer (refer to the figures below). Never apply pressures exceeding the atmospheric pressure to the analyzer which designed to introduce the gas at atmospheric pressures.

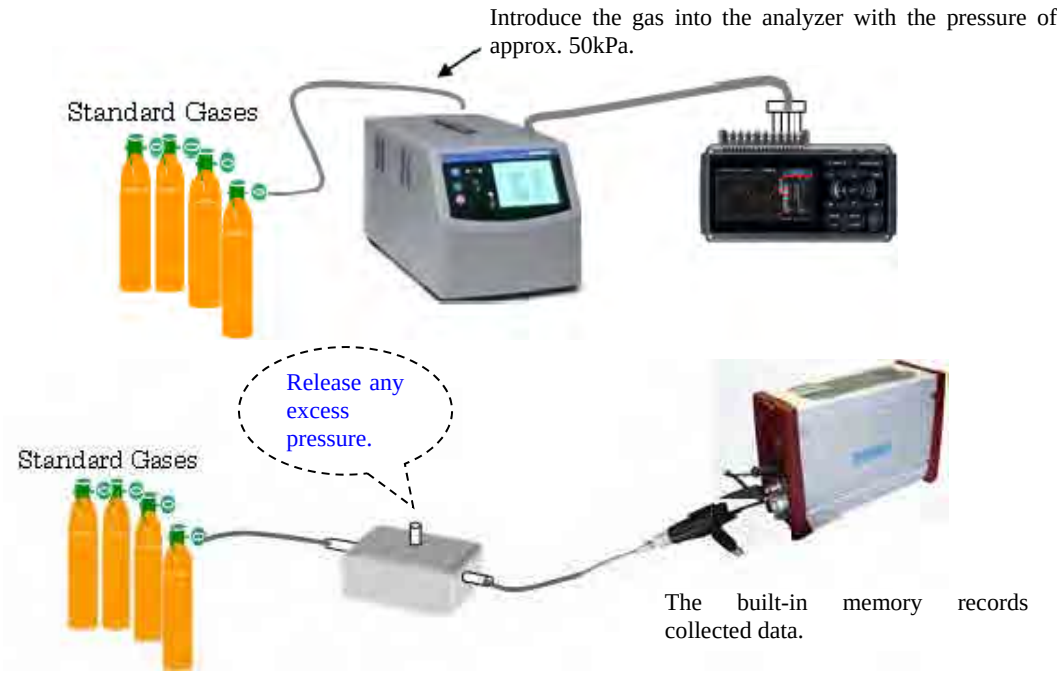


Figure 10-1 Introduction of the Standard Gas to Continuous Stack Gas Analyzers Made in Japan

The following types of standard gasses are available. Be sure to use the gasses whose validity term is guaranteed by manufacturer.

Table 10-1 Types and Concetrations of the Satndard Gasses for a Analyzer (Example)

Zero Gas	N2 Gas (Purity: 99.9999% or more)
Span Gas	SO2／N2 190ppm
	NO／N22 190ppm
	CO／N22 190ppm (for low concentration), 4% (for high concentration)
	CO2／N2 14.5%
	O2／N2 21.5%

The fundamental procedure for calibration is as follows. Conduct the span calibration following the zero calibration. It is enough to conduct these two points calibration. For the operational procedure of the equipment, refer to the technical manual.

Tbale 10-2 Calibration Procedure for a Stack Gas Analyzer

Zero Calibration	Introduce the N2 gas of a specified pressure into the analyzer through the standard gas inlet.
	Continue feeding the gas into the analyzer for one minute or more. Watching the concentration graph indicated on the logger, confirm that the indication is stabilized (in each measurement item) and the concentration is close to zero.
	Conduct the zero calibration. Do not make a too rough calibration.
	Keep the calibration coefficients on record.
Span Calibration	Introduce the standard gas of a specified pressure into the analyzer through the standard gas inlet.
	Continue feeding the gas flow into the analyzer for one minute or more. Watching the graph indicated on the logger, confirm that the indication is stabilized (in each measurement item) and the concentration is close to the level indicated on the cylinder.
	Conduct the span calibration. Do not make a calibration exceeding 2%.
	Keep the calibration coefficients on record.
	Finish the calibration. Return to the normal measurement mode.

10.1.2 Start of the Gas Component Measurement

Reconnect the piping as illustrated in 8.3.2.2 and 8.3.3 to start the flue gas measurement in accordance with the following procedure. Complete the operations up to this step while making preparations for the dust and moisture sampling equipment.

(1) Confirm that the equipment is collecting the data with the logger and the built-in memory.

(2) Start the suction pump. Confirm that the excess flue gas is sufficiently released from the manifold just behind the pump.

(3) Observe that the concentration indicated on the stack gas analyzer is approaching the concentration of the flue gas. When the indicated oxygen level is around 19%, attention is required for the possibility that the line may have leaks or be clogged.

(4) Maintain this monitoring (keep monitoring until dust and other sampling operations are completed).

(5) Watch how the concentration indicated with the logger graph changes from time to time. Carefully observe that operational changes in the boiler such as coal feeding are properly reflected in the indication.

(6) Confirm that the readings of measurement by the two measuring units for high and low concentrations are close to each other.

10.2 Preparation Work (Automatic)

Like the manual type equipment, 8.3 “Installation and Warming up of the Equipment” and 8.4 “Checks after Installation” are also required for the automated equipment operation. After finishing these steps, make preparations for the dust and moisture sampling.

10.2.1 Preparations for the Moisture Measurement

Implement the steps from (1) through (5) of 9.1.3.

10.2.2 Preparations for the Dust Sampling

For the automated dust sampler, conduct the following check operations.

1) Checking leaks from the piping

Like the manual sampler, conduct checking in accordance with 8.4.2.1, but do not connect the piping to the automatic controller main body (see the figure below), to protect the inside delicate pressure sensor from pressure shock during leak check.

For the line on the stack side, confirm that there are no leaks by sucking the line with your mouth.

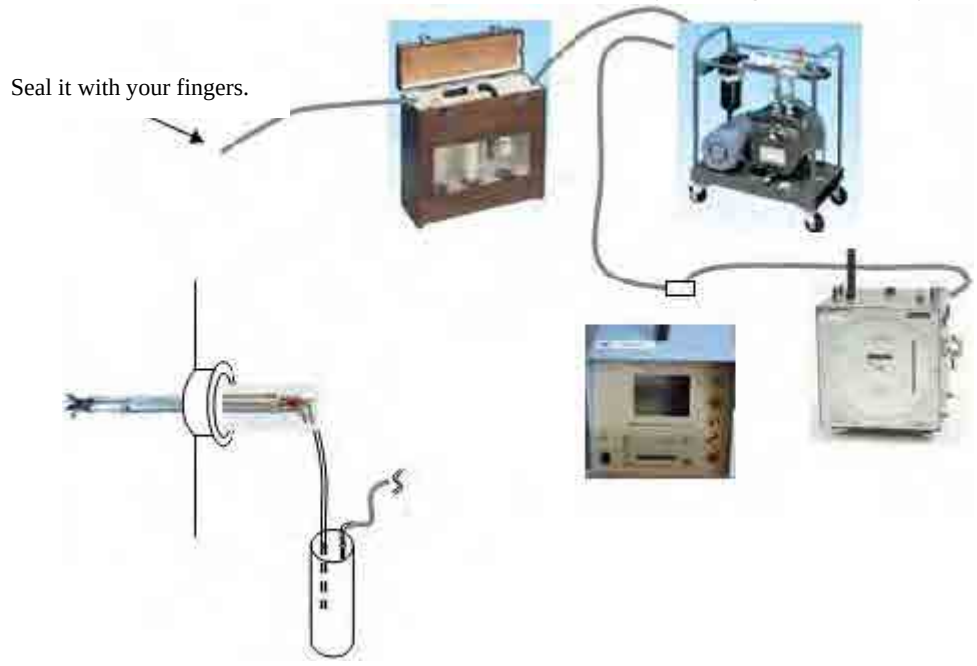


Figure 10-2 Leak Checking for the Automated Dust Sampler

2) Checks of the Controller Main Body

After turning on electricity, check in accordance with the table below.

Table 10-3 Movement Checks for the Automated Dust Sampler

Check Item	Detailed Checking
Time	Confirm that the current indicated time is correct.
Zero Adjustment for the Manometer	Remove the sampling tube and connecting pipings (in 4 colors) from the equipment back. Press the "0-ADJ" button on the front under the condition that the same pressure (atmospheric pressure) is applied to the four ports. Zero adjustment is conducted for the manometer.  Prevent these four ports from being affected by a wind. Do not seal them with your fingers (because excess pressure is applied to their inside). (For checking of the isokinetic sampler pressure sensors) After inputting 1 as the Pitot tube coefficient and 6 mm as the nozzle diameter on the screen, apply the same pressure to the red and yellow pipe. When the dynamic pressures of the two sensors are indicated as a same Pa value, the pressure sensors are normal.
Interlocking with the Suction Pump	Be sure to turn on the suction pump and manually turn the pump flow control valve almost fully opened (when much air is not fed to the main body from the pump, the flow rate control in the main body will be delayed with difficulty of operation). Confirm that the controller will automatically regulate the flow rate even if the flow control valve is manually turned to a certain position.
Printed letters of the Printer	Pull out the printer paper holder to confirm that enough paper remains. Check that the printed letters are clear and the printer starts printing at the set intervals. Also check that the necessary data is output onto the paper.

3) Confirmation of the Flue Gas Temperature and Flow Speed

Complete the connections of the equipment. Then, insert the sampling probe with no dust sampling filter into the measurement hole. Keep monitoring the flue gas pressure and temperature in the duct which are indicated on the screen of the automated dust sampler.

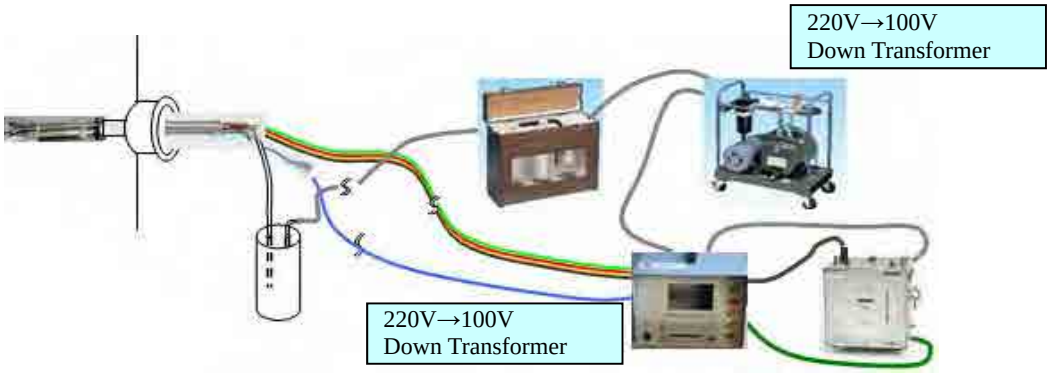


Figure 10-3 Confirmation of the Flue Gas Conditions

4) Setting of the Parameter

While checking the flue gas conditions in a simplified manner in 3), set the parameters with the controller main body. For the procedure, refer to the technical manual.

Parameter Setting	In accordance with the technical manual, conduct the "selection of the parameter and input of the values" on the screen. (Type of the fuel in use, shape of the duct, sampling method, filter attachment position, shape and material of the filter, Pitot tube coefficient, type of the gas meter, measuring method, length of the sampling time or total volume of the sampling gas, time intervals of the printer output, anticipated moisture concentration, and nozzle inner diameter)

The selection criteria for a sampling nozzle diameter are the same as shown for the manual sampler.

After completing the setting, take out the sampling probe from the measurement aperture.

5) Attachment of the Filter Head

How to set the filter paper is almost the same as 9.3. Set the nozzle with the selected inner diameter.

Attach the filter head to the sampling probe to constitute a complete unit. Adjust the positions so that the Pitot tube, the dust nozzle and the suction hose attachment opening are in the same direction.

10.2.3 Assembly of the Equipment on the Stack Side

For sampling, set a sampling probe at the measurement hole. As shown in the figure below (sectional view of the duct) shows, how to set the three sampling tubes and the temperature sensor, in addition to the sampling probe for gas component under measurement. The figure below illustrates a case where the inner diameter of the duct is small and dust sampling is made at one point, in the center of the duct.

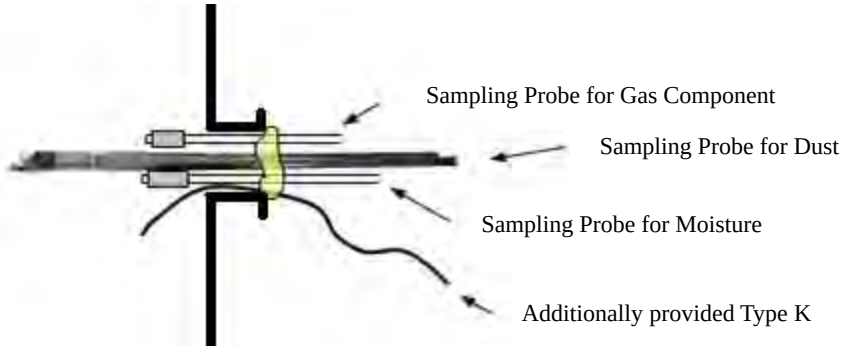


Figure 10-4 Sampling Tubes Inserted into the Measurement Hole (Duct Sectional View)

10.2.4 Immediately before Starting the Sampling

Next, complete the moisture sampling line by following the steps of (6) and (7) of 9.1.3. Read the moisture gas meter before sampling, and write it down together with the Shefield bottle numbers on the record sheet.

In addition, complete the dust sampling line as shown in the Figure 8-15 (the dust nozzle must not face the flow of the flue gas before sampling). Write down the read value of the dust gas meter before sampling, and write it down along with the number of the attached filter on the record sheet (read the value with your eyes, although the automated dust sampler automatically measures the accumulated suction volume).

Figure 10-5 Installed Equipment on the Stack Side (For the Automated Equipment)

Figure 10-6 Monitor Side Prepared for the Sampling

Like the manual equipment, confirm that the facility information record sheet and the measurement data record sheet shown in the Figure 7.2 are filled out with necessary information.

10.3 Sampling of Dust and Moisture (Automatic)

In principle, dust and moisture must be collected in the same timing and for the same length of time for the automated equipment.

10.3.1 Start of the Sampling

After confirming that the necessary lines are all connected, start the moisture and dust sampling at the same time. The main procedure is indicated in the table below.

Table 10-4 Sampling Start Procuedure for the Automated Dust Sampler

Item	Work Description
Dust Sampling	Turn the dust sampling nozzle in the same direction against the flow of the flue gas.
	Turn on the suction pump switch and the start button of the controller main body.
	Write down the sampling start time on the record sheet.
	The indication of the main body screen changes to “Under Measurement.”, Automatic control of the gas suction speed starts. The values of the “Flue Gas Dynamic Pressure Pd” and “Suction Gas Differential Pressure Vd” indicated on the screen become close to each other. When they are almost the same, the isokinetic sampling comes into effect.  Then, sampling goes on under the automatic control.
	Confirm that the indicated flue gas temperature accords with the value of the other temperature sensor indicated on the logger.
	Check the setting condition of the sampling probe on the stack side and the condition of the trap bottle again.
	Check the set parameters again.
Moisture Sampling	Same operation as the manual type equipment: Follow the step (9) of 9.1.3. However, it is possible to decrease the suction flow rate to around 0.5L/min.
	Write down the sampling start time on the record sheet.

For the continuous stack gas analyzer, watch how the concentration changes again referring to the logger graph indication.

Check that the indicated values of the measuring equipment for high concentration and for low concentration become close to each other.

10.3.2 During the Sampling

The check points for the moisture sampling are the same as (10) of 9.1.3.

The check points for the dust sampling are almost the same as (7) of 9.3. The isokinetic sampling controlled by the automated equipment is different from the manual type equipment.

As shown in Table 10-4, confirm that the dust sampling is automatically controlled under the isokinetic sampling conditions. The automated sampler prints the control and other conditions with the printer at the set intervals. Regularly check that there are no abnormalities.

Even under the automatic control, isokinetic sampling sometimes does not work. In that case, it is necessary to manually operate the flow control valve of the pump so as to return it to the position easy to control. This happens due to any extreme flue gas condition at the site such as the flow speed drastically fluctuating or due to the low flow speed, to which the controller cannot properly respond. If the suction rate extremely goes to the maximum or the minimum under the out-of-control condition, the BZ lamp lights and the buzzer sounds. In this case, operate the flow control valve immediately so as to return it to the position where the automatic control works.

10.3.3 End of the Sampling

The steps for the moisture sampling are the same as (11) and (12) of 9.1.3. Sampling of moisture contents is finished at the same time when dust sampling is complete.

When the sampling flow rate (or time) designated through the parameter setting reaches the target, the equipment automatically finishes the sampling and the stop lamp lights (but manually turn off the suction pump when the pump is plugged into a different power outlet from that of the main body).

Pull out the sampling probe from the duct, and collect the first cylindrical filter like the manual sampling. Read the gas meter, and write it down on the record sheet as the value after sampling.

10.3.4 Sampling of the Second and Third Sets

The procedure for the automated equipment is the same as that for the manual equipment. Conduct the second and third moisture samplings in the same timing as the dust sampling.

After completing the first dust sampling, repeat the above steps of “3) through 5) of 10.2.2, 10.2.3 and 10.2.4,” and start the next sampling. Use three cylindrical filters or more per boiler.

10.3.5 Moving Sampling Method

As for the moving sampling method, follow the step in (10) of 9.3.

11. Completion of the Entire Monitoring and Pullout

After collecting three samples each for dust and moisture, complete the entire monitoring, following the procedure specified in the table below. The operations which differ between the manual equipment and the automated equipment are shown separately. For the removing the equipment, bring back the equipment to the vehicle, following the installation procedure in the reverse order. Be sure to pay attention to the safety during the operation.

Table 11-1 Operations to Finish the Entire Monitoring (Automatic)

<table>
<tr><th rowspan="2">Item</th><th colspan="2">Outline of the Operations</th></tr>
<tr><th>For the Manual Equipment</th><th>For the Automated Equipment</th></tr>
<tr><td rowspan="2">Gas Component Sampling</td><td colspan="2"><For the Chemical Sensor-type Gas Analyzer>
(1) After analyzing the sample gas, let normal air flow through the analyzer to prevent the sensor from deteriorating. The purging time differs according to the type of analyzed gas and the length of analysis time (refer to the manual). For purging, the longer the better.
(2) Turn off the measuring equipment to place them in their cases. Confirm that analyzed values are output on the record sheet.
(3) Pull out the sampling probes from the measurement hole, and put them in their dedicated case together with the main body.</td></tr>
<tr><td colspan="2"><For the Continuous Stack Gas Analyzer>
(1) Leave the sampling probe pulled out of the measurement hole on the floor until it gets cool.
(2) Stop the suction pump. Let the atmospheric air flow through the analyzer for several minutes.
(3) Complete the data recording with the logger and the memory. Then, transfer the recorded data from the logger to a USB.
(4) Operate the analyzer and the logger to stop them in accordance with the technical manual. Detach the signal lines and the power cables.
(5) Pipings: Purge water if there is any inside. Roll them for pickup.
(6) Put back other equipment in their dedicated cases.</td></tr>
<tr><td>Moisture Sampling</td><td colspan="2">(1) Pull out the sampling probe from the measurement hole. Put back the Shefield bottles into the case.
(2) Confirm that all necessary monitoring records are output on the record sheets.
(3) Detach the pipings from the gas meter, the pump and other apparatuses to put them back into the shelf and the storage boxes. Be careful not to break their glass parts.</td></tr>
<tr><td rowspan="3">Dust Sampling</td><td colspan="2">(1) Confirm that the dust-sampling cylindrical filters are placed in the storage box.</td></tr>
<tr><td>(2) (None)</td><td>(2) You may turn off the power soon after the equipment finishes automatic sampling.
Collect the paper sheets output from the printer (record the place and the date).</td></tr>
<tr><td colspan="2">(3) Confirm that all necessary monitoring records are output on the record sheets.
(4) Put back the sampling nozzle into the case, and check that all nozzles are in place. Clean up dirty nozzles, if any.
(5) Remove any dust from the surface of the detached sampling probe to put it back into the dedicated case.
(6) When the wet type gas meter is used, take out antifreeze from the inside (to return it into the container).
(7) Put back the gas meter and other apparatuses into their dedicated cases.
(8) Pipings: Remove water if there is any inside. Roll them for pickup.</td></tr>
<tr><td>Others</td><td colspan="2">(1) Confirm the on-site data documents such as “record sheets, memories collecting data, and output paper sheets from the printer,” and take them back to the office in one lump.
(2) Take away the pipes, the thermocouple, the sampling tube and others from the measurement hole. Fix the cover placed on the hole with screws.</td></tr>
</table>

	(3) Return the provided power cables and any other articles to the facility, if any. (4) Retrieve the operation condition record sheet and make sure all data are written on it at control room. (5) Load all equipment you brought to the site onto the vehicle. Check each of them for confirmation so that nothing is left behind. (6) Clean up the monitoring site, and bring back all refuse to the office. (7) Report to the facility manager that the monitoring is completed, and go back to the office. (8) After returning to the office, unload the equipment and samples to place them in the equipment room on that day.

Figure 11-1 Pullout Scenes

12. Storage of the Equipment and Samples

When returning to the equipment room, complete the following operations on that day.

(1) Put back the equipment into the shelf or in their original places.

Conduct maintenance for necessary equipment on the same day if it is minor work. If their maintenance requires much time, mention it in a notebook so that the maintenance work will be done at a later date.

Figure 12-1 Storage of Equipment

(2) Put the record sheets and the printer record sheets of the automated dust sampler you brought back to the office into the dedicated file.

(3) Transfer the cylindrical filters for dust sampling from the storage container to the desiccator (check the post-measurement weight at a later date, following the procedure specified in Table 7-3). For the data reduction procedure, refer to the technical manual.

(4) Tell the superior that all work is completed, and this is the end of all operation.

5 Stack Gas Measurement Procedure for HOBs

Capacity Development Project
for
Air Quality Control in Ulaanbaatar City, Mongolia

Stack Gas Monitoring Guideline
for
Heat Only Boiler (HOB)

November 2012

Contents

1. How to Use This Book

The JICA Project' Capacity Development Project for Air Quality Control in Ulaanbaatar City' measured air pollutants in discharged gas from boilers during two winter seasons in Ulaanbaatar City, and obtained representative data of their concentration and emission factors. The instructions and work procedures are shown in this guideline based on actual field monitoring for measurement of air pollutants emitted from a stationary source.

This HOB Stack Gas Monitoring Guideline is one of three Guidelines prepared for three typical pollution sources: 'Coal Power Plant, Heat Only Boiler (HOB) and Ger Stove.'

This book shows the entire stack gas monitoring schedule for a boiler in Chapter 6, and details of task procedures or instructions are shown in from Chapter 7 to Chapter 12 in order.

There are many complicated task procedures in this method; however, conventional measurement techniques are used. The details of task procedures such as the equipment operation procedures are separately summarized in other technical manuals as a reference, because the details of every procedure are not necessary all together in one book. The measurement rules commonly applied for three Stack Gas Guidelines are prepared as the 'Stack Gas Monitoring Protocol' shown below.

Table 1-1 Technical Reference Materials

No.	Material Name
1	Stack Gas Monitoring Protocol
2	Installation Procedure of Measurement Hole on a Chimney
3	Wet Sampling/Analysis Procedure for Gases
4	Moisture Measurement (Technical Manual)
5	Temperature Measurement (Technical Manual)
6	Flow Rate Measurement (Technical Manual)
7	Automated Stack Gas Analyzer TESTO (Technical Manual)
8	Automated Stack Gas Analyzer PG (Technical Manual)
9	Automated Stack Gas Analyzer HT-3000 (Technical Manual)
10	Automated Isokinetic Dust Sampler (Technical Manual)
11	Data Reduction Procedure (Technical Manual)

2. Purpose of Stack Gas Monitoring

In Mongolia, hot water necessary for people's daily living and their industrial activities is produced mainly by burning coal in thermal power plants, small boilers (HOB, CFWH), and household stoves.

The thermal power plants constitute the core of the large-scale hot water supply network for the central part of the city. In areas without the supply of this hot water, each city block is provided with a small boiler and forms a zonal heating system using the boiler. Thereby, the hot water is supplied to ordinary houses and public facilities (schools, hospitals, etc.) in the vicinity of the small boiler. In the surrounding areas and some isolated areas that do not even have this type of hot water supply network, coal stoves are used in ordinary houses and ger.

Air pollution becomes heavy in winter and is considered to be generated mainly by the combustion of coal in these fixed generation sources. In order to reduce the pollution, it is necessary to regularly measure the amount of air pollutants discharged from the fixed discharge

sources.

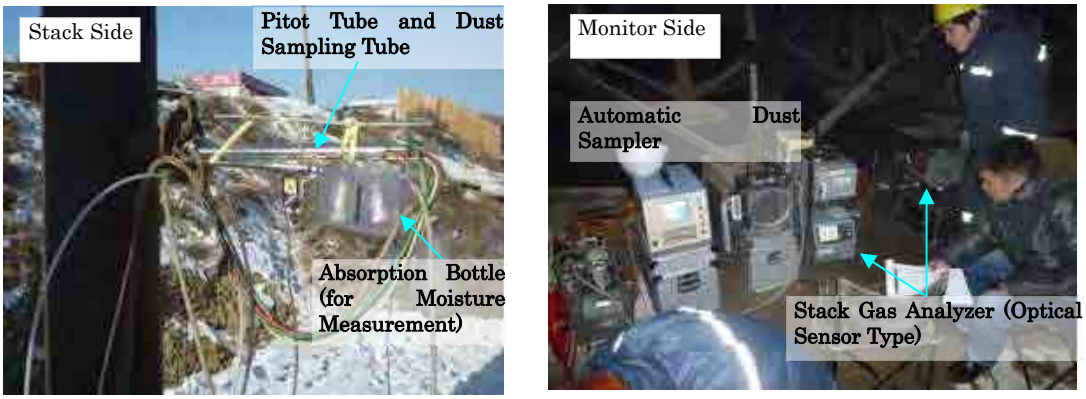


Fig. 2-1 Stack Gas Monitoring

3. Features of Monitored Boiler

The boiler to be monitored is the small coal boiler (heat only boiler: HOB) that constitutes the zonal heating system in Ulaanbaatar City.

In areas that are not covered by a hot water supply network that uses a thermal power plant, hot water is supplied by a HOB that is locally installed. The hot water is used for heating rooms, cooking, washing etc. Discontinuation of the supply of hot water is vital for the people and, therefore, the HOB operates without any discontinuation in winter. Many of HOBs have a capacity of 1 MW or lower.

When one HOB covers one residential zone, hot water is supplied to ordinary houses and relatively small public facilities (schools, hospitals, and public offices) around the boiler regardless of whether they are public or private. The fee for the hot water is collected based on the amount of hot water used in each house or facility. The HOB is often operated and managed by a private boiler operation company.

Many companies and stores (such as supermarkets) that have large-scale facilities install a dedicated boiler to each building and operate and manage the boilers by themselves.

Fig. 3-1 Coal Feeding Work for HOB

Fig. 3-2 Example of a Heat Supplied Area Covered by a Boiler

Boiler operators are employed only in winter and they operate the boilers day and night in shifts without any discontinuation. In Mongolia, the winter is long and the boilers are in constant

operation except in the summer (June to August). The winter from November to March is the peak of the boiler operation and, therefore, the coal consumption is increased and the amount of discharged pollutants is also increased in this season. Because the operation rate is high, the furnace is usually damaged in two or three years and the whole boiler needs to be replaced.

The HOBs in Ulaanbaatar City are mainly manufactured in Mongolia, Russia, Korea, China, Czech, or Hungary. The small coal boilers have low energy efficiency and many of them have no discharged gas treatment equipment installed therein. Many of the domestically manufactured boilers have inferior performance. The domestic manufacturers are advancing technically and copying the designs of foreign boilers. However, defective boilers are still left with non-operational condition.

In the areas where no funds are available to replace boilers, people have to continue to use old-fashioned boilers and the domestic manufacturers replace and repair damaged parts such as heat exchanger pipes.

3.1 Constituent Parts of a HOB

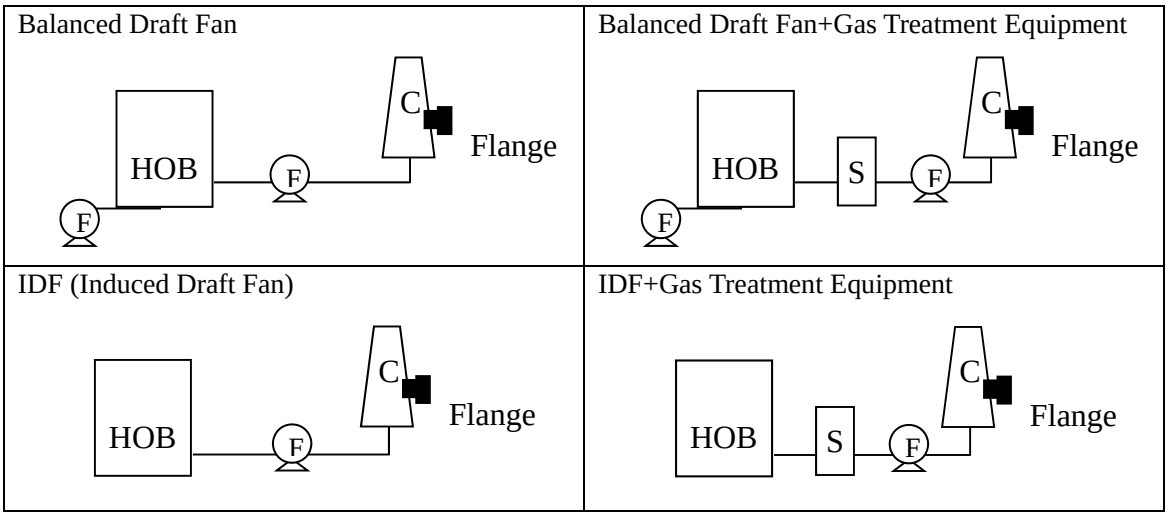
As to only the gas line, a boiler facility consists of the following main parts:

Table 3-1 Major Components of HOB

Section	Major Component
Main Body of Boiler	Furnace, fire grate, heat exchanger tube, coal feed inlet, outlet for ash
Draft Fans	FDF, IDF
Gas Treatment Unit	Cyclone, bag filter, wet scrubber
Duct	Horizontal or vertical duct
Chimney	Made of cast iron or brick
Others	Air preheater, damper, automatic coal feeder or ash discharger

The small coal boilers in Ulaanbaatar City can be classified into the following six types by noting the parts that influence the amount of discharged pollutants (draft fans and gas treatment units):

(F: Fan, HOB: Main Body of Boiler, S: Gas Treatment unit, and C: Chimney)



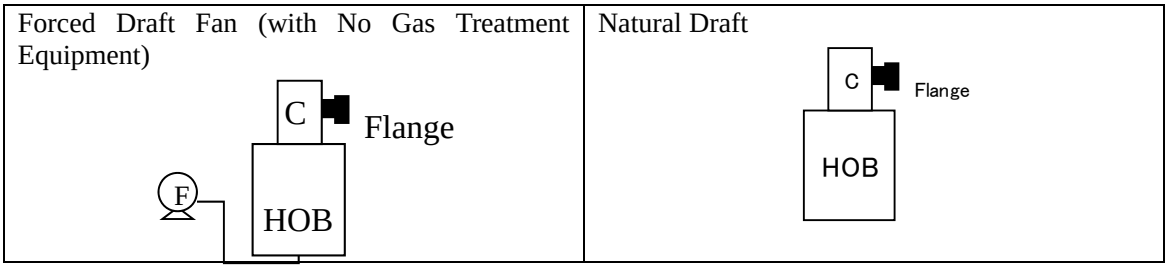


Fig. 3-3 Type of HOB

3.2 Structural Factors Influencing Flue Gas Conditions

Table: 3-2 shows the major operational factors that influence the flue gas measurement value. The 'structural factors' in this table correspond to the contents in Section 3.1. Both structural and operational conditions influence the amount of discharged pollutants.

Table 3-2 Factors Influencing the Flue Gas Conditions

	Structural Factors	Operating Factors
Coal Feeding	Automated or manual type	Time interval, amount (related to hot water demands), size, kind and components of coal.
Ventilation	Natural, forced, induced or balanced type	ON-OFF timing, and adjustment of damper travel
Gas Treatment Unit	Cyclone, wet scrubber, bag filter type	Maintenance condition
Others	Boiler types	Raking for ash removal and clinker discharging

4. Measured Items and Measuring Equipment

'Measurement Items and Methods' and 'Outline of Measurement Equipment' are respectively described in Chapter 4.2 and Chapter 4.3.

The equipment for gas analysis and dust sampling should be chosen according to its merits, as shown below.

4.1 Differences between Two Types of Gas Sensors

The upper half of the following table shows the differences between two types of gas sensor methods. To evaluate the measurement accuracy and reliability of the values reported for each method, the lower half of the table gives one of the three grades: 'high, middle, and low.'

Table 4-1 Performance Difference between Stack Gas Analyzers

Sensor Type of Stack Gas Analyzer		Chemical Sensor	Optical Sensor
Feature	Concentration range	Covers both low and high concentration range.	
	Deterioration of sensor	Easy deterioration in high concentration interference gas.	Robust
	Measurable time range in continuous monitoring	A few minutes especially in high concentration CO gas	Long time range (hours) in every gas condition
Data Collection	Total number of data and sampling timing	Three data for a boiler at random timing	Hundreds of data for a boiler Every 10 seconds during the whole sampling time
Calculation of Reporting Value	Calculation of the average concentration	Average of few data	Averaging hundreds of data
	Calculation of the average concentration (after O_2 conversion)	Unsatisfactory representative result due to few sampled O_2 data	Good representative result based on hundreds of sampled O_2 data
Quality of Measurement Accuracy	At calibration	Middle (Sensor sensitivity degrades gradually during several months by being affected by interference from sample gases.)	High
	Appropriateness of the gas sampling method	High	High
Validity of Sampling Condition Chosen	Setting of the measurement timing	Low	High
	Sampling time period	Low	High
Reliability of Report Value (Gas Concentration)	Calculation accuracy of O_2 conversion value	Low	High

Chemical Sensor Type

Optical Sensor Type

Figure 4-1 Stack Gas Analyzers Used

4.2 Differences between Two Types of Dust Sampling Equipment

Table 4-2 Differences in Equipment Performance/Use and Data Calculation for Dust Sampling

Type of Dust Sampling Equipment		Manual Type	Automatic Type
Use	Isokinetic sampling control	Read out the gas condition every two seconds, and adjust the sampling speed manually	Continuous automatic control
	Total number of data sampling timing	Three samples for a boiler, taking around 20 minutes for a dust sample. The sample timing and time length are to be determined by actual operative information of a target boiler.	
Calculation of Reporting Value	Calculation of average concentration	Arithmetic mean of three data	Time-weighted average concentration of three data
	Calculation of average concentration (after O_2 conversion)	Unsatisfactory representative result due to few (three) sampled O_2 data	Good representative result based on hundreds of sampled O2 data
Operability	Quickness of control	Middle	High
	Accuracy of control	Middle	High
Validity of Sampling Condition Chosen	Start timing	High	High
	Sampling period	High	High
Reliability of Value for Reporting (Dust Concentration)	Calculation accuracy of O_2 conversion value	Middle	High

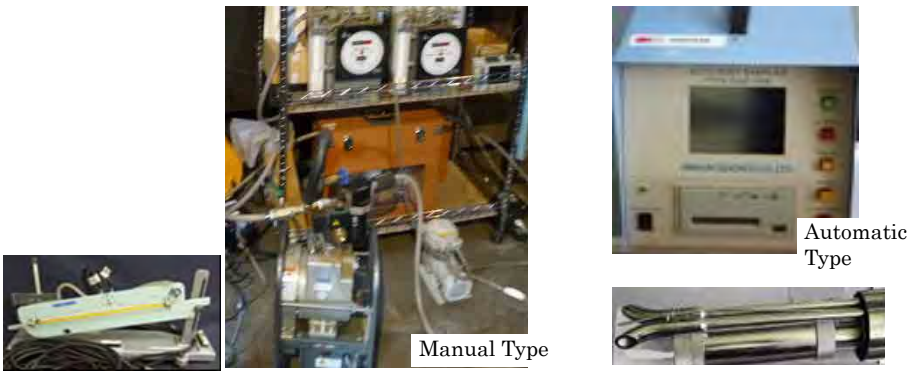


Fig. 4-2 Dust Samplers Used

4.3 Features of Equipment for Measurement in Winter

Special care should be taken to prepare equipment for out-door monitoring in Ulaanbaatar City because the temperature can fall to minus 30 or 40 degrees in a severe winter season.

Table 4-3 Freeze Prevention for Monitoring Equipment

No.	Name	Method
1	Inclined Manometer	Use an anti-freeze solution as the inner liquid such as ethyl alcohol.
2	Gas Meter	Use the dry type gas meter. If the wet type is used, it will require anti-freeze solution.
3	Power Cable	Use a cold-resistance power cable to prevent short circuit problems due to a hard frozen cable malfunctioning.
4	Gas Sampling Tubes (Connection Cables between Chimney Side and Analyzer Side)	Use a silicon braid hose for moisture and dust measurement. A Teflon tube must be used for gas component measurement.
5	Trap Box	Use plastic bottles to prevent the moisture in the sample gas from concentrating and freezing inside the sampling tube for gas or dust measurement use.
7	Heat Resistant Material	Wrap the sampling tube with insulation piping.

5. Technicians for Measurement

The technicians to perform the stack gas measurement must satisfy the following requirements:

Table 5-1 Qualification for Stack Gas Monitoring Technician

No.	Requirement
<As the capacity of a monitoring team>	
1	The team must be the owner of stack monitoring equipment as shown in Chapter 4, or should be an organization that has the capacity to borrow the equipment.
2	Owner of a laboratory, or the person who has the capacity to use a laboratory as a work place for weighing samples or maintaining equipment.
3	Capable of procuring a van to carry the equipment to the monitoring site.
4	Capacity to assign two or more experienced technicians for the stack monitoring work on a boiler. (Beginners must not be counted as experienced staff members.)
5	Self-management capacity to generate a report voluntarily and honestly when problems occur with the monitoring equipment during its use. Capacity to pay to fix malfunctioning equipment.
<Personal Qualification>	
1	A person who participated in the training course of stack gas monitoring in a JICA project, or has rich experience of performing actual monitoring in power plants or on HOBs.
2	More than 30 times of monitoring experience on site
3	Capability to operate the isokinetic dust sampling
4	A high level of understanding to use the dedicated dust calculation software.

6. Monitoring Steps

An overview of the boiler stack gas monitoring steps for the boiler will be described. The monitoring steps on the day are detailed and will be described in Section 6.1.

Table 6.1 Monitoring Steps and Contents of Monitoring

No.	Time	Contents
1.	Preparation	① Notification and coordination of monitoring schedule for the manager of the target boiler ② Verification of measurement site by preliminary inspection ③ Arrangement of vehicles and drivers to carry the equipment ④ Provision of necessary supplies of consumables. ⑤ Confirmation of equipment status
2.	The Previous Day of Measurement Day	① Selection of equipment used for stack gas measurement ② Maintenance for: e.g. absorption bottle, trap box ③ Conditioning and pre-weighing of dust filters ④ Preparation of field recording sheets ⑤ Equipment preparation for loading
3.	Measurement Day	See Section 6.1
4.	The Next Day of Measurement Day	① Post-weighing of filter with sampled dust for dust measurement ② Data reduction and report production

6.1 Example of Monitoring Schedule on Measurement Day

An overview of the monitoring will be described following the flow of the measurement work for one day.

Some of the steps from the installation to the ending of the monitoring differ depending on whether manual operation equipment or automated equipment is used, as shown in Table 6-2.

Table 6-2 Work Flow on Measurement Day

	No.	Work Flow	
		With Manual Operation Equipment	With Automated Equipment
Transportation	①	Loading of the equipment on the carrying vehicle.	
	②	Departure to the target boiler.	
	③	Arrival at the target boiler.	
Verification of Monitoring Site	①	Greeting to operator of the boiler. Verification of room layout and work space for equipment installation inside/outside the boiler house.	
	②	Unloading and shifting of the equipment at the measurement site (the monitor side and the chimney side).	
	③	Preparation of power supply. Cleaning of the work place for equipment installation.	
	④	Interviewing the boiler operator (about general information of the boiler, operating schedule on the measurement day, the coal type, etc.). Record the information as a field note.	
Installation & Warming-up of Equipment	①	Determination of the equipment setting position inside the room. Performing the piping and wiring task between the monitor side and the chimney side.	
		Equipment: Gas meters, inclined manometer, etc.	Equipment; Gas meters, automated isokinetic sampler, etc.
	②	Warming-up of the stack gas analyzers. Turn ON the electric heater if it is cold inside the room.	

	③	Confirmation of the operability of the suction pump and the PC in the working environment.	
	④	Weighing of the absorption bottles as pre-weighing. Record as a field note.	
	⑤	Open the cap of the measurement hole on the chimney. Rake the accumulated ash and clean the inside of the pipe. Attach the supporting rod on the flange of the measurement hole. Arrange the piping and the wiring of sampling tubes, the temperature signal code and the power cable.	
	⑥	Measure the chimney inner radius and the flange length protruding from the chimney, and record them as a field note.	
	⑦	Calculate and record the measurement position on the cross-sectional area according to the size data of the chimney.	
	⑧	Wind pieces of adhesive tape around the sampling tube or the Pitot tube to mark the sampling positions where the tips of the sampling inlet are to be set on a cross-sectional area in a chimney.	
		Pipes to be marked: Pitot tube and dust sampling tube	Pipe to be marked: Only the integrated dust sampling tube
	⑨	Start up the PC and open the designated calculation sheet (Excel). Input the facility information and the measured atmospheric pressure value.	
		Use the calculation sheet for manual sampling. Use the dedicated barometer to measure the atmospheric pressure.	Use the calculation sheet for automated sampling. The automated dust sampler indicates thereon the measured value of atmospheric pressure.
	⑩	Join the tubes from the chimney side with tubes from the monitor side. Put the drain trap box into both the dust sampling line and the gas measurement line. Take measures against the cold climate to avoid moisture freezing inside the tubes. Check the leakage of the tubes.	
	⑪	Insert the sampling pipes for the gas measurement and the moisture sampling, and the temperature sensor. Using heat resistant tape, fill the gap between the hole and sampling pipes.	
	⑫	Determine the starting and the/ending timings for the dust or the moisture sampling based on the information gathered from the boiler operators. Record the coal feeding and turning ON/OFF timings of the fan until the end of the dust measurement.	
	⑬	Calibrate the stack gas analyzers by introducing reference gases. Then, start measurement of gas measurement items in the 'measurement mode.'	
Basic Measurement	①	Measure and record the temperature of the flue gas.	No basic measurement is required when the automated dust sampler is used.
	②	Measure and record the flue gas speed.	
	③	Take the moisture samples. Weigh the samples and record the results.	
Dust Sampling	①	Input the results of the basic measurement into the designated spreadsheet. Measure new static/dynamic pressures and the temperature of flue gas, and input those data again. Calculate the isokinetic sampling speed of the dust and determine the nozzle inner diameter to sample the dust. Fit the sampling probe into the measurement hole after assembling the sample head.	Determine the nozzle inner diameter for the dust sampling according to the displayed data such as flue gas speed, etc. Assemble the moisture sampling apparatus and install it in the measurement hole.
	②	Take three dust samples according to the guideline 'Stack Gas Measurement Protocol.'	
		Read out the instantaneous value of the dynamic pressure and the temperature displayed on devices every one minute, and adjust the sampling speed frequently.	The dust sampling is controlled automatically. Moisture sampling must be performed at the same timing as dust sampling.
	③	Keep the dust sample filter in the dedicated glass holder, and finish the entire measurement.	

Withdrawal	①	Retrieve the record sheet, the samples and the memories. Demount and reassemble the integrated equipment at both the chimney and the monitor sides and re-load all in carrier vehicle.
	②	Clean the place where the equipment was installed. Let the boiler operator know that you have finished work and are leaving.
Storage	①	Put the equipment back in its original position on the shelves in the office. Place the record sheets in a file. Check the condition and conduct maintenance work for the equipment if it is required.
	②	Keep the dust sample filters in the desiccator after drying them in a drying oven.

6.1.1 When Manual Operation Equipment Is Used

Figure 6-1 shows an example of the monitoring steps for the day of measurement. The item numbers in Fig. 6-1 correspond to those in Table 6-2.

Because the operation conditions and the stack inner diameter differ for each boiler, the time necessary for conducting the basic measurement and the dust sampling may be longer than that in the table below. When the gas components are collected and analyzed using the moisture sampling, the basic measurement and the work back in the laboratory after the sampling shall additionally be conducted.

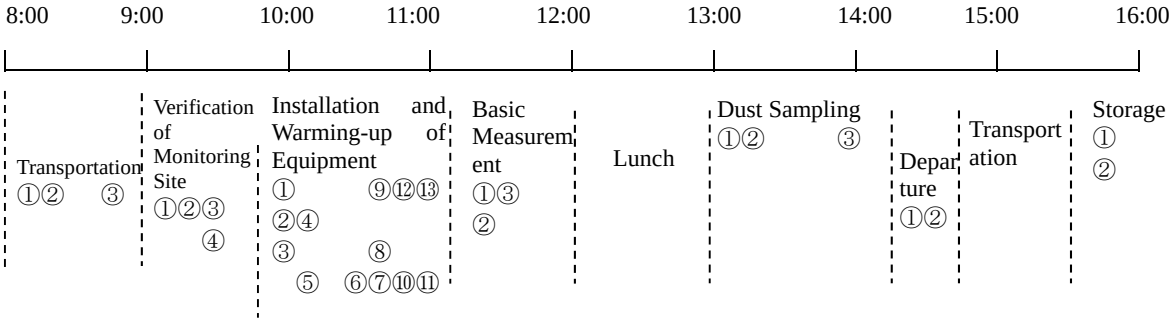


Fig. 6-1 Flow of Monitoring on Day of Measurement

6.1.2 When Automated Equipment Is Used

The monitoring steps are almost the same as those for using manual operation equipment apart from the absence of basic measurement, etc.

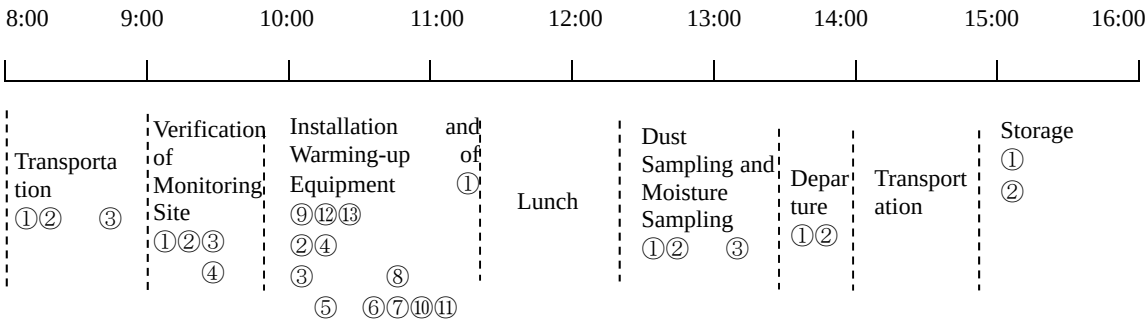


Fig. 6-2 Flow of Monitoring on Day of Measurement

7. Preparation before the Day of Monitoring

Before the day of the measurement, communication with external organizations, preparation and checks on the equipment to be used, etc., are conducted. This preparation is important for efficiently conducting the monitoring and avoiding mistakes on the measurement day.

7.1 Pre-Arrangement

7.1.1 Preparatory Notification to the Manager of the Boiler Facility to Be Monitored and, Coordination and Determination of the Day of Measurement

At least 10 days before the measurement day, call the boiler facility for which the measurement is planned and request permission for measurement. Obtain as much information as possible from the boiler operator to check whether the boiler is operating normally with no malfunctions and that the boiler will be in operation as usual on the day of the measurement. Based on the outcome, the steps planned by both sides are checked to determine the day of the measurement.

For boilers on army and police facilities, permission to visit must be applied for in writing. It takes time to obtain permission (one week or more).

In some boiler facilities, a boiler management company employs boiler operators to manage the operation. Therefore, communication should be conducted not only with the boiler operators but also with the management company.

7.1.2 Verification of Monitoring Site

When the day of the measurement has been determined on the phone, the state of the site should further be checked on the phone such as whether the space for the measurement work can be secured. For the facility to be measured for the first time, a preliminary visit should be made before the actual measurement.

Some sites may impose the following difficulties on the measurement work:

Table 7-1 Points to Be Checked in Preliminary Visit to Site

Defect	Countermeasure
The duct has no measurement hole.	According to the Guideline "Installation Procedure of Measurement Hole on a Chimney," newly install the hole. The cost for the new hole shall be borne by the measuring party.
The space in which to position the measuring equipment is small.	It may be possible to operate the measuring equipment in the carrier vehicle.
The power supply is unstable.	When the power supply cannot be stabilized, the boiler is excluded from the boilers to be measured.
The power capacity of the power supply is insufficient.	The insufficient amount shall be complemented by obtaining other power from a neighboring house or using a power generator.
The stack is clogged and the flue gas is not smoothly discharged.	The stack shall be excluded from the stacks to be measured. This stack shall be measured after the stack is replaced.
The measurement hole is installed at a high position and it is dangerous to use it.	The stack shall be excluded from the stacks to be measured.
The scaffold around the duct is dangerous.	

7.1.3 Arrangement of Vehicles and Drivers to Carry Equipment

Vehicles to be used on the day of measurement (for monitoring technicians and to carry the equipment) and drivers for them shall be secured in advance. Employment agreements with them shall be concluded also in advance when necessary.

7.1.4 Provision of Necessary Supplies of Consumables, etc.

In the monitoring, the consumables shown below (examples) are used. Therefore, sufficient consumables shall be supplied.

Dust filter, plastic tape, wire, silicone tube, silica gel, $CaCl_2$, cotton work gloves (which shall be reused after washing to the extent possible)

It shall be confirmed early that no device is faulty.

7.2 Preparation on Previous Day of Measurement

7.2.1 Selection of Equipment to Be Used

The features of the performance of the main devices are as shown in Chapter 4. Table 7.2 shows simplified options for each of the devices.

A combination of the automated stack gas analyzer and the automated isokinetic dust sampler is determined as the best combination taking into consideration the large number of data collected, the measurement precision, and the simplicity of measurement work.

Table 7-2 Features of Manual Operation and Automated Devices

Use of Device	Name of Device	Feature
Gas Speed Measurement	Inclined manometer (as a pressure gauge)	The operation is complicated and the accuracy is low.
	Automated isokinetic dust sampler	Operation and recording are automated and the accuracy is excellent.
Analysis of Gas Components	Wet type gas sampler (SO_2, NOx)	Only one piece of data can be obtained and it is difficult for this data to represent the status.
	Stack Gas Analyzer (TESTO)	Few data can be obtained and it is difficult for these pieces of data to represent the status.
	Automated Stack Gas Analyzer (PG-250) Automated Stack Gas Analyzer (HT-3000)	The data can continuously be obtained and the data has high capability as representative data.
Dust Sampling	Manual isokinetic dust sampler	The gas speed and the temperature vary significantly in a coal boiler. The manual control of these items tends to be inaccurate. Therefore, the accuracy is intermediate.
	Automated isokinetic dust sampler	The control is automated and the accuracy is relatively high.

7.2.2 Maintenance of Equipment Used, and Pre-Process and Pre-Weighing of Dust Sampling Filter

The preparation of the dust-sampling filter shall be started in the morning of the previous day of sampling. The following operations shall be conducted on new cylindrical filters (Five or more filters shall be prepared for one boiler):

Table 7-3 Preparation Procedure for Dust Cylindrical Filter

No.	Preparation Procedure for Paper Filters
1	When the stack gas temperature is low, select glass-fiber cylindrical filters. When the stack gas temperature exceeds 200℃, select silica-fiber tube-type paper filters.
2	Provide each of the cylindrical filters with a serial number (see the filter weighing sheet). Handle the filters with clean hands to avoid dust contamination.
3	Place the cylindrical filters longitudinally in a beaker (with their openings upward) and put the beaker as it is in an oven.
4	Dry them in the oven at 110℃. Turn OFF the oven after one hour and leave the beaker to cool.
5	When the beaker is somewhat cooled, move the beaker with the paper filters in it using a pair of tongs into a dedicated desiccator.
6	Leave the beaker to be cooled in the desiccator as it is for two or more hours in its dry state until the temperature of the filters becomes room temperature.
7	Take one of the filters out of the desiccator and immediately weigh each filter using a 10^{-4}-g scale. Record the weight of the filter as a pre-sampling weight with the filter number.
8	Store the filter after weighing it. Place the filters in the cylindrical filter case (the dedicated glass bottle) or the case that has been storing the new paper filters.

Silica Filter

Dryer


Filters are dried.


The paper filters are cooled in the desiccator to room temperature.

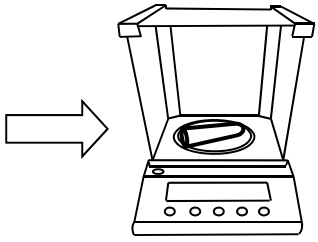


Fig. 7-1 Preparation of Dust Paper Filter

As the maintenance of other devices, for example, the following checks, cleaning, etc., shall be conducted:

Table 7-4 Important Points of Device Maintenance

Clean the dust-sampling nozzle. Check the presence of packing of the dust sampling tube.
Maintenance of absorption bottle (Sheffield bottle): When 1/3 of $CaCl_2$ is dissolved, replace the bottle. When the portion around the cock is clogged with silicone grease, clean the clogged portion. Remove the stain on the gas inlet. Conduct checks on leakages and clogging.
When the inclined manometer is used; Check whether the alcohol is present.
Oil Pump: Discharge only the contaminated oil. Check whether the position of the oil level is normal and, when the oil is insufficient, replenish with new oil.
Dry-Type Gas Meter: When no temperature is displayed, replace the battery.
Stack Gas Analyzer: Check whether a significant shift is observed for the response value when the reference gas is introduced.
Check whether any of the pipes is clogged with water or dust. When any leakage is found, cut off the leaking portion.
Check the inexpensive electric appliances (such as plugs and electric heaters) have no disconnected wires.

7.2.3 Preparation of Field Recording Sheet

Each field recording sheet (in Mongolian) is prepared. Make copies from the original sheet.

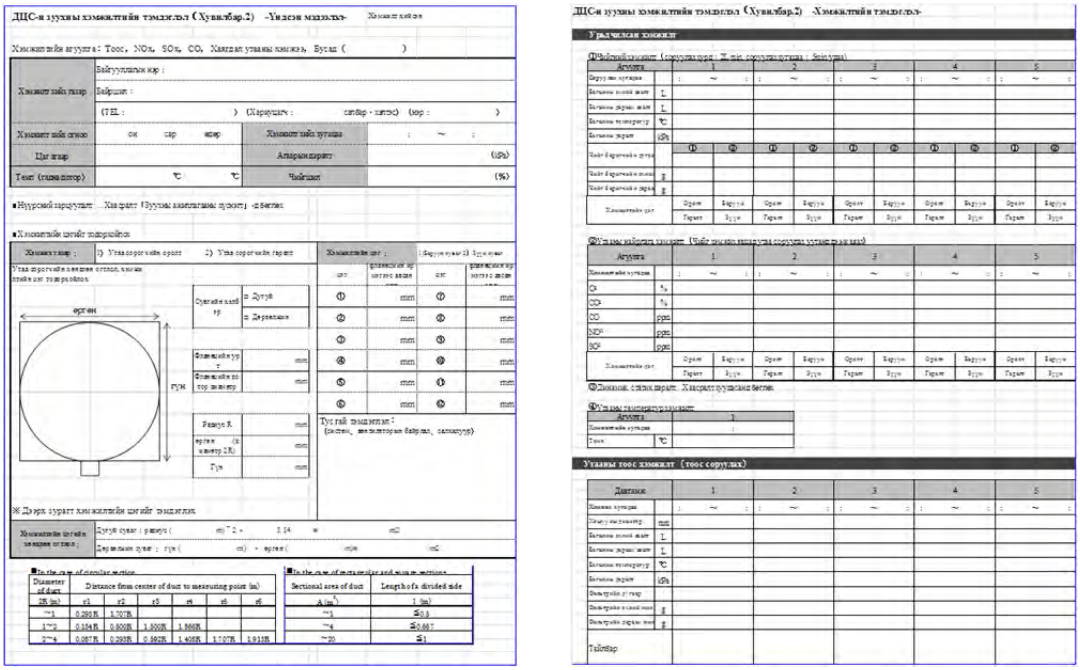


Fig. 7-2 Field Recording Sheet (Example)

7.2.4 Preparation for Carrying Equipment

If the devices were gathered in the morning of the day of the measurement, there would be insufficient time. All the devices to be used shall be prepared and gathered in the machinery room on the previous day. Use the device checklist to ensure that no necessary devices are left behind.

8. Work Steps to Be Performed before Measurement (Day of Measurement)

The procedure and remarks will be described for each work step according to the order of items in Table 6-2.

8.1 Move to Boiler

On the previous day, load all the devices collectively put in the machinery room, onto the device carrier vehicle. Move the devices quickly using a dolly to avoid breakages.

Fig. 8-1 Loading of Devices

Pay attention to the following items when loading the device on the vehicle:

Table 8-1 Points Requiring Attention in Loading Devices on the Vehicle

Carefully arrange the devices to be put in the cargo room on the vehicle to avoid damage caused by driving on bumpy roads.
Do not crush soft items by putting hard items on them or next to them.
Use cushions for fragile items and put the fragile items in baskets to the extent possible.
Always put precision instruments in their dedicated carry boxes.
Using ropes, fix items to avoid movement when the vehicle drives on bumpy roads. Otherwise, sandwich these items between heavy items.

When the vehicle is involved in heavy traffic after starting from base, contact the manager of the boiler to inform the manager of the delay and the estimated arrival time.

When the condition of the road surface is bad, drive the vehicle slowly to avoid breaking the devices loaded thereon due to bumps on the road.

8.2 Checks to Be Conducted on Site (Immediately after Arrival)

8.2.1 Greeting, Checks on Working Space, Carrying-in of Devices

After arrival, take time to greet the boiler operators and obtain permission to enter the premises. After obtaining permission, drive the vehicle into the premises.

The leader of the measurement team shall observe "the inside of the boiler room and the vicinity of the stack" and shall check the spaces in which to install the devices (because the measuring devices are installed being divided into two for the two positions of the stack side position and the monitoring side position).

The positions shall be determined under consultation with the boiler operators taking into consideration the size, the location, the piping of each working space not to interfere with the work of the boiler operators.

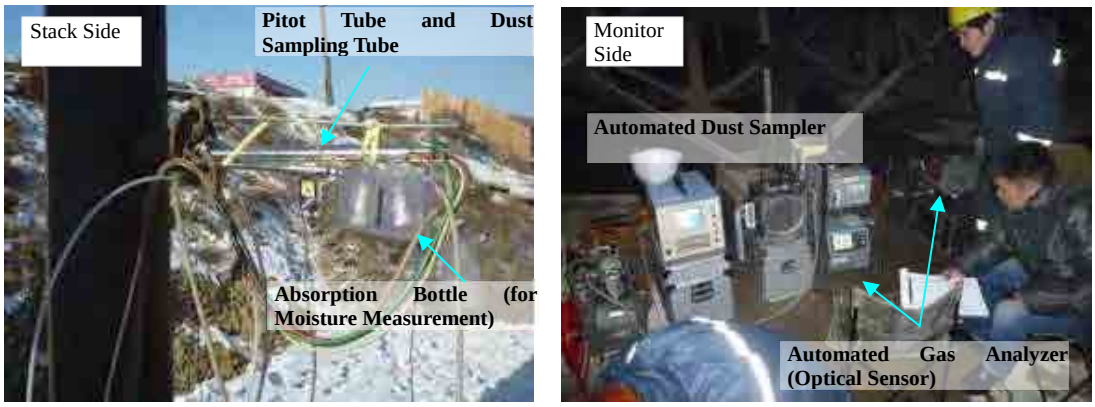


Fig. 8-2 Representative Example of Device Installation

The size of the boiler room and the positions of the measurement holes differ depending on the facility and, therefore, the arrangement of the devices is changed as follows according to the place.

Table 8-2 Difference in Device Installation Space

Case	Stack Side	Monitor Side
1	The measurement hole is located inside the room and all the monitoring steps can be conducted in a warm room. These are excellent conditions.	
2	The measurement hole is located on the stack outside the building and the devices for the stack side have to be installed around the stack.	The working space can hardly be secured in the boiler room but the rest room can be used separately as a space for the stack gas analyzers.
3		No working space can be secured in the room and the measurement has to be conducted with the devices for the monitor side loaded on the vehicle. Two vehicles are necessary.

It is necessary to put the stack gas analyzers, the oil pump, the PC, etc. in a warm room for them to operate. In the winter in Mongolia, air pollution becomes heavy and the temperature may fall to -30℃. When cold air enters the room, the temperature may fall to -10℃ or lower. In this

operation environment, some devices may lack measurement precision even though they seem to operate. Therefore, care must be taken to select the places in which to install the devices.

Fig. 8-3 Difference in Installation Place for Stack Gas Devices

Take care of the following points when the measuring devices are installed close to the boiler:

Table 8-3 Points to Requiring Attention in Selecting the Installation Positions

Observe the behavior of the boiler operators. Taking into consideration the behavior of the measurement technicians, the devices must be installed in positions that do not interfere with the boiler operators and the measurement technicians.
The position must have electric outlets available for the measurement and must be within the range for the power cable to reach.

The positions must allow the piping and wiring to be installed to connect the stack side and the monitor side.
The positions must be free from dripping water and secure from large trash falling on the measuring devices.
The room must be ventilated so that smoke from the boiler does not accumulate in the room.
The positions must be away from any rotating fan motor (especially, the rotational belt).
The positions must be away from the boiler to prevent overheating.
The scaffold on the stack side: The scaffold must be installed in a sufficient space that is not slippery, too high, or easy to fall from.

Ask the boiler operators where the electric outlets are (two or more outlets are preferable) and secure the power by connecting the power source drum to the outlets. After determining the installation positions, remove any trash and obstacles around the installation positions.

8.2.2 Interview for Facility Information, Operation Schedule, etc.

When the installation positions of the devices have been determined and the carrying of the devices has started, the leader of the measurement team shall interview the boiler operators to obtain information on the facility operation. Simultaneously, the information shall be recorded on the record sheet (see the table on the right).

Based on this information, the measurement schedule shall be determined for the day of the measurement (the starting time of the measurement and the length of sampling time).

The information obtained in the interview will be useful when the validity of the calculated report value is verified in the data reduction conducted on a later day.

① Operation Policy for Day of Measurement

The timings to feed coal, to remove the ash, and to turn ON/OFF the induction fan, and at what intervals.

Is the combustion of the coal close to that in winter or is it suppressed in comparison?

② Demand Origin of Hot Water

Where to supply hot water, how large is the quantity, the time zone of the demand, and the actual operation state at nighttime.

③ Boiler

The model, the coal feeding method, the discharged gas treatment scheme (dust removal and desulfurization), and checks on faulty parts

④ Coal

Place of production, type, size, and the average weight of one shovelful of coal

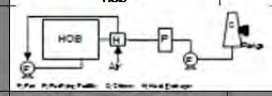
No.		1	
HOB Model		0000	
Photograph		 HOB  Stack	
System (for one stack)			
Item for Record		Content (Example)	Remarks
Basic Item	Place of Installation	0000	
	Date of Visit	Jan. 28, 2012	
	Temperature of Day of Visit	Average: -23 degrees (Max.: -13 and Min.: -31)	
Specification of Boiler	Capacity (MW)		
	Date of Installation		
	Quantity	One	
	Fan Type	Equivalent	
	Coal Feeding Type	Manual	
	Measurement Hole Position	Stack	
	Dust Sampler Type	Cyclone	
	Desulfurizer Type	None	
State of Operation	Supplied Water Set Temperature (℃)	80	
	Fan Operation Scheme	Intermittent Operation	
	Timings to Turn ON and OFF Fan	Fan is turned OFF when the returning water is 80℃ or boiler, and is turned ON when the returning water is around 70℃.	
	Leakage into Stack, etc.	A slight blowout before the stack	
	Use of Damper	Not available	A damper is used.
	How to Put out Clinker	Pushing out into a clinker receiver behind the HOB	
	Frequency of Clinker Removal	Before every coal feeding	
	Frequency of Raking Coal	Several times an hour	
	Maintenance of Dust Collector	Cleaning once in a half day	
Items for Fuel	Type of Coal	Natural	
	Size of Coal	Powder coal	About several centimeters
	Container to Feed Coal	Shovel	
	Coal Feeding Time Interval	Once in 20 minutes for about 10 shovelfuls	
	Feeding Amount at Time of Visit (kg/h)	220	
	Midwinter Feeding Amount (kg/h)	270	
	Other Items to Burn	Sometimes, paper trash	
Demand for Hot Water	Demand Origin	Schools, hospitals, and houses around the boiler	
	Demand Time Zone	All day long (no supply discontinuation)	
Other Items Observed or Interviewed		- The coal is fed such that the thickness of the coal on the fire grate is 8 to 12 cm. - The tracing HOB is operated only in the cold season. - The coal is supplied to plural HOBs each at a different timing from each other. - Coal feeding is regulated based on the observation of the quality of the ash.	

Fig. 8-4 Example of Boiler Information Record

8.3 Installation and Warming up of Equipment

The place for installing each device differs depending on: the composition of the devices and the layout of the facility; and which devices are used. The installation and the warming up of the devices depend on whether the devices used are manually operated or automated and whether the position of the measurement hole is inside or outside the facility.

8.3.1 Safety Measures

8.3.1.1 Items to Wear

Fig. 8-5 Items for Workers to Wear

8.3.1.2 Points Requiring Attention when Working in High-Places

A large-scale boiler may have a high stack and may also have a measurement hole at a high position located five to six or more meters from the ground. The stack-side devices described in Items 8.3.2 and 8.3.3 shall be installed around the measurement hole and the piping and the wiring (such as the power cables and the temperature compensating conductors) are also installed around it.

Install the stack-side devices using ropes and take the safety provisions into consideration. Lift the devices with two persons as a team synchronizing the timing between the two by using a sign.

<Stack Side> Check the scaffold carefully. Tie the end of the rope to a rail of a fence, etc. Wind the unused portion of the rope tightly not to obstruct the work and to avoid fouling of the rope on the legs of the technicians.

When an article is lifted up, lift the article slowly directly upward to avoid the article swinging.

<Monitor Side> Wind the rope once around the device to be lifted (if the rope is tied at only the handgrip of the device, the lid of the device may open and the articles retained therein may fall out). When the lifting has been started, the persons standing under the device must move away to avoid standing beneath the device.

When a pipe lifted up is fixed, take into consideration the position to fix the plastic pipe to avoid being squashed by its own weight.

Correctly Fixed

Incorrectly Fixed: The pipe gets squashed by its own weight where it is fixed.

Fig. 8-6 How to Fix the Pipe

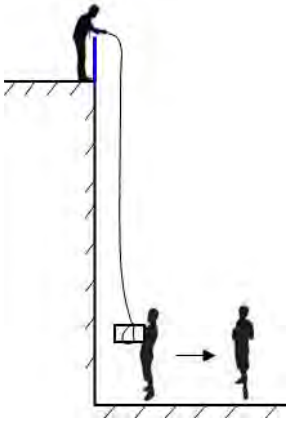


Fig. 8-7 Lifting up of Device

8.3.2 For Outdoor Duct

When the duct is located outdoors, the pipe to introduce the stack gas becomes cold due to the ambient air and the large amount of steam, which is included in the stack gas, freezes in the pipe. With no countermeasures taken, the pipe becomes clogged several minutes after the monitoring is started and no gas can pass through the pipe. This point requires the most attention in installation.

8.3.2.1 Configuration and Connection for Manual Operation Devices

1） Temperature Measuring Device

A thermocouple of the K type shall be used as the temperature sensor. There are two types of apparatus for displaying the temperature data (the portable temperature display or the logger). The logger not only displays the temperature but also records and stores the temperature every second.

Fig. 8-8 Temperature Measuring Devices

The logger is often used because it can automatically record. The logger can accept other input signals (such as a measurement output of the stack gas analyzer) and, therefore, the logger shall be installed on the monitor side. When the distance is long between the stack side and the monitor side, the sides shall be connected using a long "dedicated temperature compensating conductor" (an ordinary signal line must not be used).

2） Gas Speed Measuring Device

The Pitot tube and a pressure gauge are used to measure the stack gas speed. A pressure gauge as a manual operation device is an inclined manometer.

Fig. 8-9 Gas Speed Measuring Device

The inclined manometer includes a liquid sealed therein and is used together with the liquid. In winter in Mongolia, the liquid must not freeze and, therefore, the liquid shall be ethyl-alcohol, which has a low freezing point (where available).

The Pitot tube and the inclined manometer are connected using two tubes and, when the distance is long between the stack side and the monitor side, the section in between may be connected by silicone hoses or Teflon tubes.

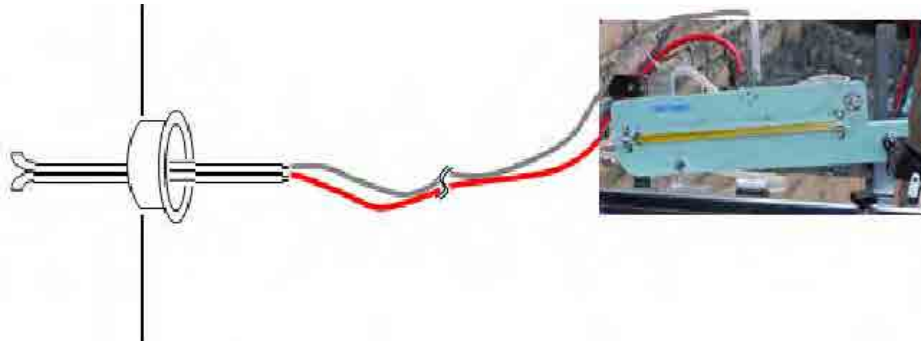


Fig. 8-10 Image of Installation of Gas Speed Measuring Devices

3） Moisture Sampling Devices

The stack-side devices consist of "the sampling tube, the Sheffield bottle, and a ribbon heater."

The monitor-side devices consist of "the trap, the suction pump (with a flow regulating cock), and the gas meter." The devices made in Japan include those that are driven at AC100V and it is necessary to use transformers to reduce the voltage from 220 V to 100 V.

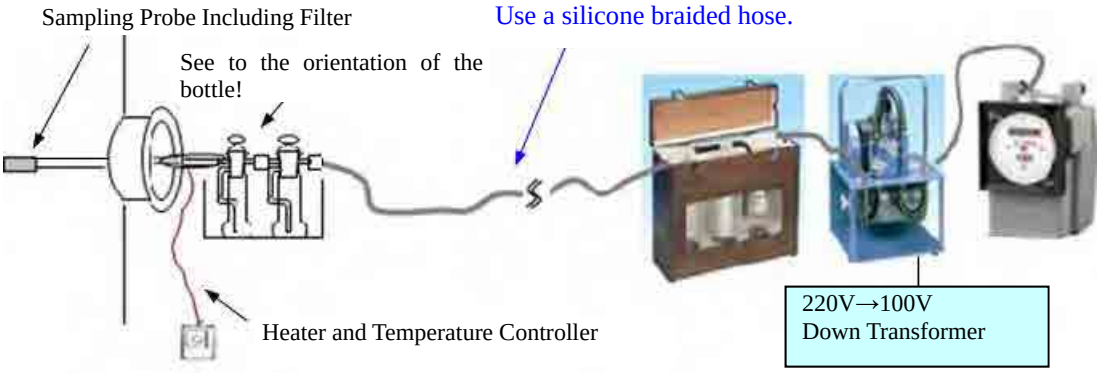
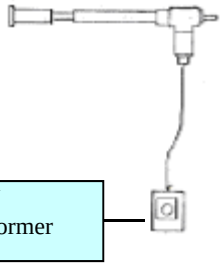


Fig. 8-11 Image of Installation of Moisture Sampling Devices

The Sheffield bottle is a tool for capturing only the steam in the stack gas. The sampling probe must be attached with a filter to avoid entry of dust in the stack gas into the Sheffield bottle. Because the ambient air is cold, the piping extending to the Sheffield bottle needs to be heated by a heater as shown in Fig. 8-7 (without the heating, the steam changes into water droplets, which do not enter the Sheffield bottle).



When the steam is adsorbed, the steam generates heat and the Sheffield bottle becomes hot. Therefore, the lower half of the bottle is usually sunk in the water tank (however, in winter, the atmosphere cools the bottle and the water tank is unnecessary).

A heating sampling probe as shown in the figure on the right may be used instead of "the sampling probe plus the ribbon heater."

4） Gas Component Measuring Devices (SO_2, NOx, CO, CO_2, and O_2）

The manual operation devices for measuring the gas components in the stack gas are roughly classified into the following two types:

① Wet Type Gas Sampling Set

See the Moisture Analysis Technical Manual. This book does not introduce this set because the measurement can be conducted only several times and the data is too poor to be used as representative data.

② Stack Gas Analyzer (Chemical Sensor Type)

The HOB often discharges CO gas whose concentration exceeds 1,000 ppm. Therefore, the sensitivity of the chemical-sensor stack gas analyzer is degraded due to the degradation of the sensor. For this reason, measurement of a high-concentration CO gas for a long time must be avoided. The measurement must be finished in a short time and it is necessary after obtaining one measured value to purge the line in the analyzer with the air in the room for a while.

To avoid the degradation of the sensor to the extent possible, the following measures shall be employed for the sampling (with this measuring method, the stack side and the monitor side are never connected to each other):

- Sample the stack gas in the gas bag using the twin balls. Sample the stack gas slowly taking five minutes for one bag (suction regularly to fill the bag such that the concentration of the sample in one bag after the sampling averages the gas concentration which fluctuates in five minutes).
- Analyze the concentration of the sample in the gas bag in a short time using the chemical-sensor stack gas analyzer and obtain one piece of data as a five-minute average value.

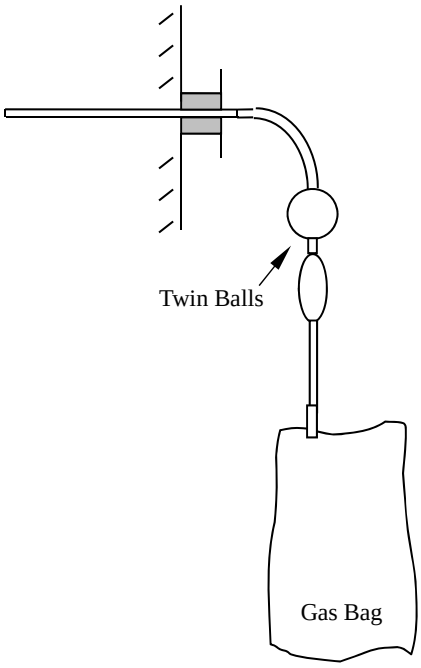


Fig. 8-12 Image of Installation of Gas Component Measuring Devices

The stack gas analyzer needs to be placed in a warm room (because its operation temperature is 0 to 40℃).

The measurement in this method only gives several pieces of data for one boiler and the data is poor as representative data similarly to that given by the Wet analysis method.

5） Dust Sampling Device

The stack side consists of "the dust sampling probe." The dust nozzle and the tube-type paper filter are set in the sampling probe.

The monitor side consists of "the trap, the suction pump (with the flow regulating valve), and the gas meter." The devices made in Japan include those that are driven at AC100V and it is necessary to use transformers to reduce the voltage from 220 V to 100 V.

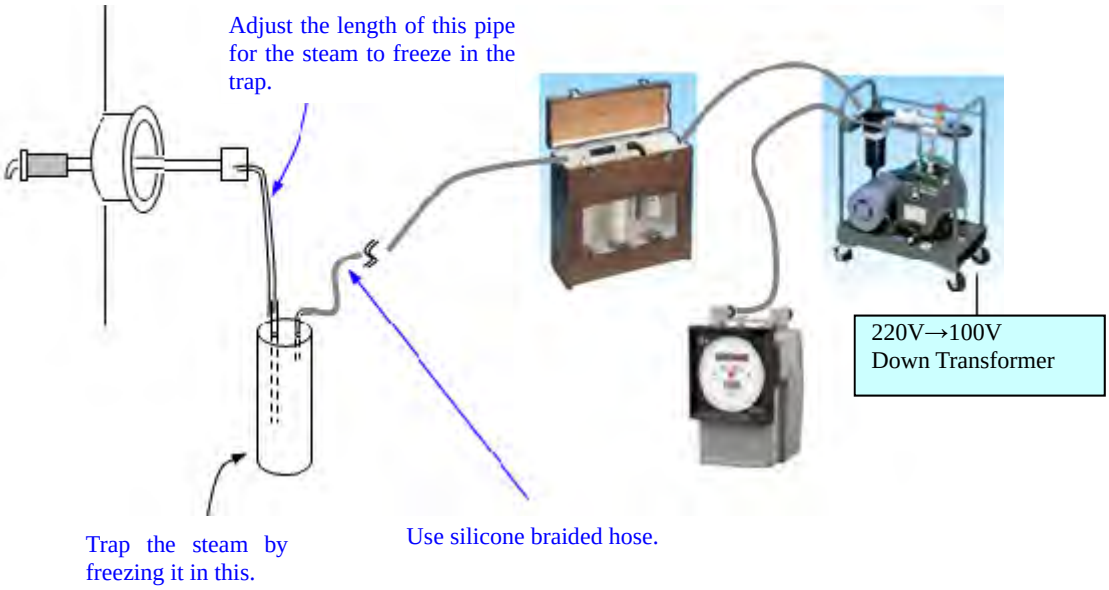


Fig. 8-13 Image of Installation of Dust Sampling Devices

8.3.2.2 Configuration and Connection for Automated Devices

As the configuration of the devices, the following items are different between the automated devices and the manual operation devices:

Table 8-4 Difference between Automated Devices and Manual Operation Devices

Name of Device	Difference between Automated Device and Manual Operation Device
Moisture Measuring Device	No difference. The same device is used for the manual measurement and the automated measurement.
Gas Component Measuring Device	Automated stack gas analyzer is used as the automated device.
Temperature Measuring Device	As the automated device, the automated dust sampler automatically measures both the temperature and the gas speed.
Gas Speed Measuring Device	
Dust Sampling Device	

An image of the installation of the automated devices is shown below.

1） Moisture Sampling Device

Same as that of the manual operation device.

2） Gas Component Measuring Device (SO_2, NOx, CO, CO_2, and O_2)

The stack gas analyzer (optical sensor type), which is robust against the influence of the interfering gases and can continuously measure, collects data of the concentration at a rate of a piece of data in 10 seconds (in the current setting).

The dust and the moisture in the stack gas must not enter the stack gas analyzer. As shown in the figure below, the parts for removing the dust and the moisture are inserted at various positions of the stack gas introducing line.

As to the coal boiler, the CO concentration sometimes becomes high that is in order of %. To precisely measure the concentration from a low concentration to a high concentration, prepare a stack gas analyzer for a low concentration and that for a high concentration and operate them in parallel to each other. According to the flow, suction the stack gas using a small pump and, thereafter, distribute the gas to input the gas into each of the measuring devices.

The devices made in Japan include those that are driven at AC100V and it is necessary to use transformers to reduce the voltage from 220 V to 100 V. It takes one hour to warm up the automated stack gas analyzer and, thereafter, it takes a further 30 minutes because the calibration must be conducted using the reference gas. To quickly conduct the measurement work, it is important to pre-warm the automated stack gas analyzers by installing these devices earlier than the other devices such as the dust samplers.

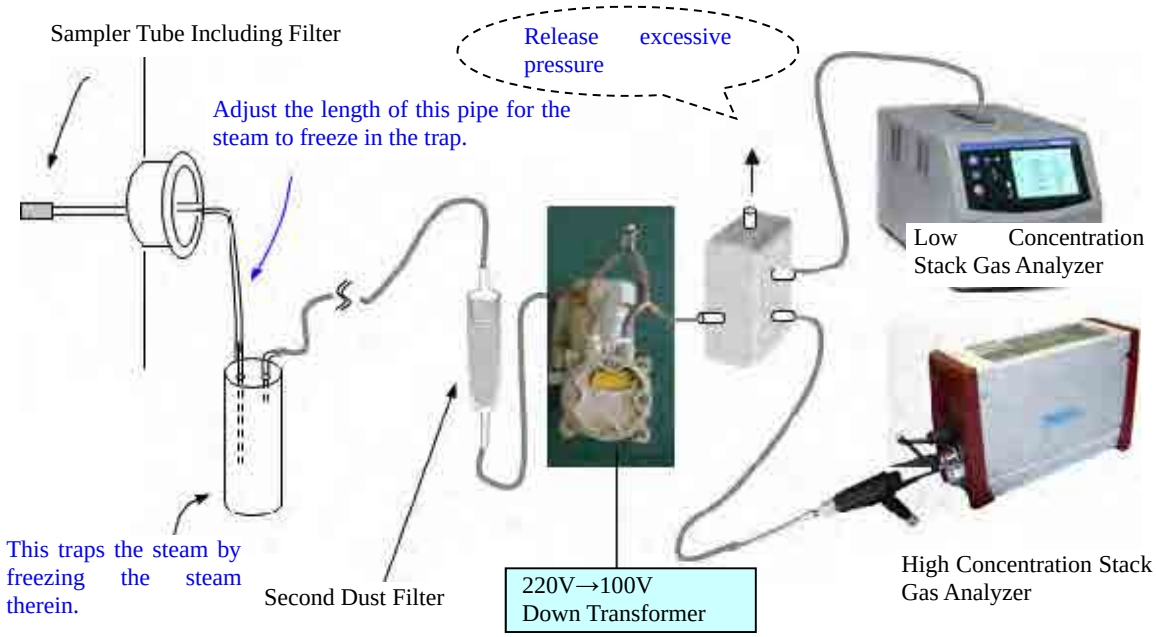


Fig. 8-14 Image of Installation of Automated Gas Component Measuring Devices

The data is automatically recorded into the logger by the low concentration stack gas analyzer and into an incorporated SD card by the device for the high concentration.

An uninterruptible power source shall be prepared for a power failure. This source can maintain the operation for several tens of minutes during a power failure.

3） Dust Sampling Devices

The stack side consists of "the dust sampling probe." The dust nozzle and a cylindrical filter are set in the sampling probe.

The monitor side consists of "the trap, the suction pump (with a flow regulating valve), the gas meter, and the sampling controller." The devices made in Japan include those that are driven at AC100V and it is necessary to use transformers to reduce the voltage from 220 V to 100 V.

Gas meters include wet-type gas meters and dry gas meters. When a wet-type gas meter is used, put antifreeze liquid in it.

See the technical manual for the piping and connection to the automated dust sampler.

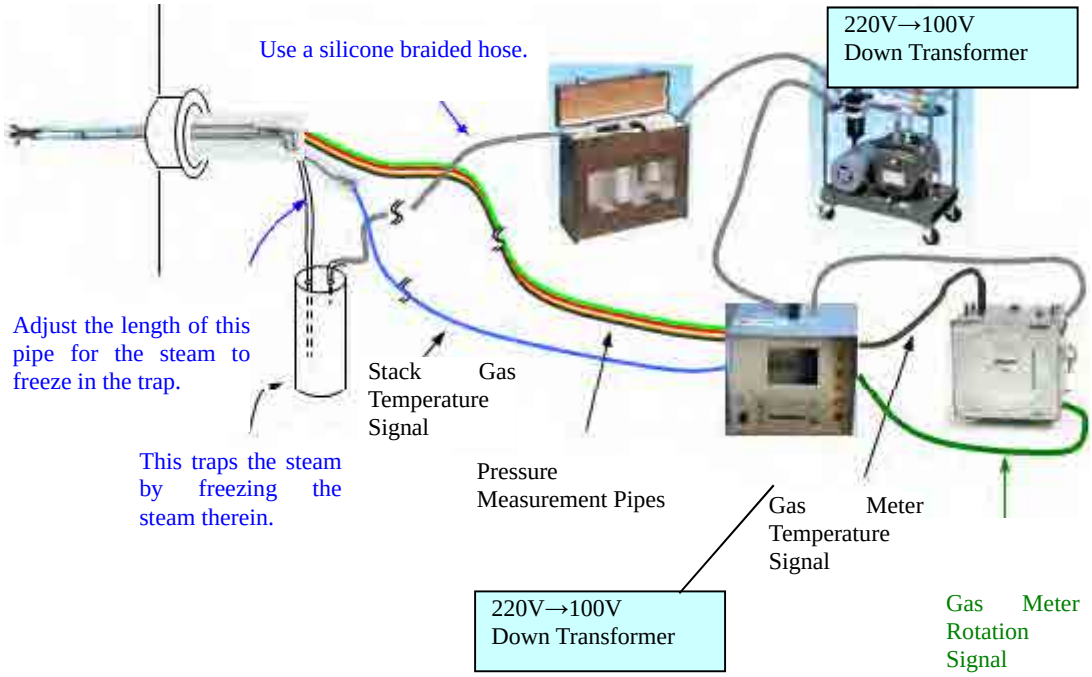


Fig. 8-15 Image of Installation of Automated Dust Sampling Devices

8.3.3 For an Indoor Duct

As to installation of the devices, the difference from 8.3.2 "For an Outdoor Duct" is that the length of wiring and the signal lines are shorter from the duct to the monitor side. In addition, when it is warm in the room, the "trap bottle" for trapping the steam does not need to be installed immediately after the sampling tube.

However, the floor of the room for the HOB is often cold due to the incoming cold atmosphere from the outside and, therefore, the steam in the stack gas becomes water in the piping and runs on the floor.

As to the dust sampling devices, the steam changes to water in the pipe and, thereafter, the water is captured by the trap box and causes no problem. However, in the automated gas component measurement line, it is necessary to introduce a measure to avoid any water from entering the automated measuring device by, for example, inserting a trap bottle as shown in the figure below.

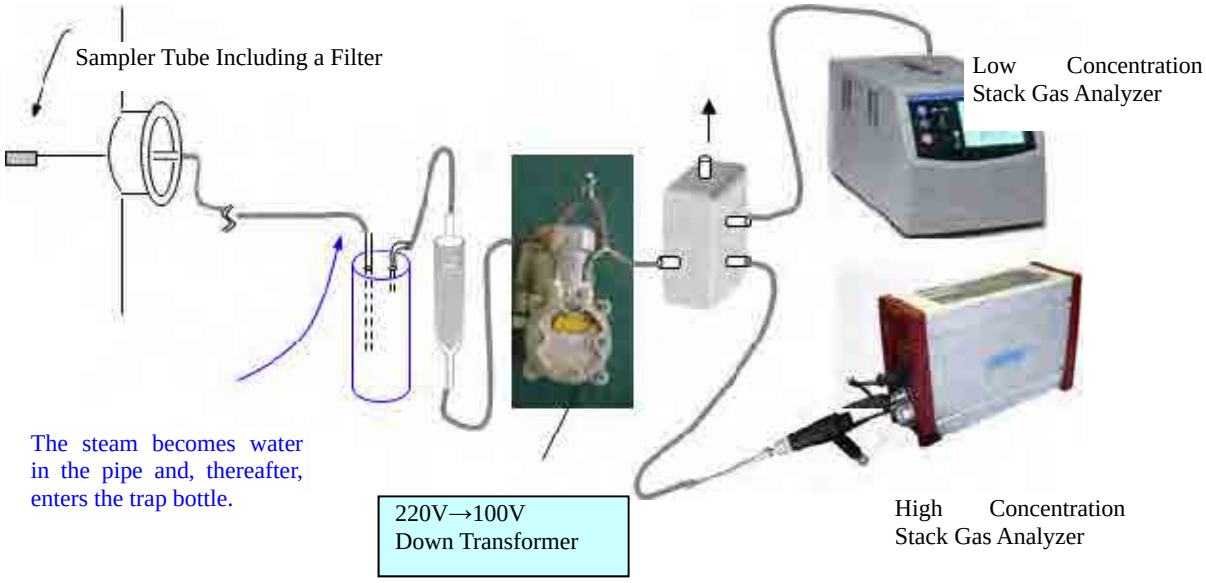


Fig. 8-16 Image of Installation of Gas Component Measuring Devices (in Warm Room)

An uninterruptible power source shall be prepared for a power failure. This source can maintain the operation for several tens of minutes during a power failure.

8.4 Checks after Installation

8.4.1 Checks on Operation

The following checks shall be conducted to check whether the main devices operate normally:

Table 8-5 Items to Be Checked after Warming up

Name of Device	Item to Be Checked
Suction Pump	Start up the oil pump immediately while the pump is warm after it is installed. When the room is cold, heat the oil tank. Once the pump is turned on, keep the pump rotating (because, when the room is cold, it is difficult to turn ON the pump again once the pump is turned OFF).
Gas Meter	When the pump is connected to the gas meter and is turned on, check that the gauge of the gas meter rotates round and round.
PC	The PC does not work well when the room is cold. Warm the PC properly using an electric blanket.
Stack Gas Analyzer	Turn ON this analyzer immediately after its installation (because it takes one hour to warm up the analyzer). Put the analyzer in the state for suctioning the room atmosphere. Connect the analyzer to the logger. (Conduct the operations following the technical manual.) If the stack gas analyzer is placed in the vehicle, the stack gas suctioned by the analyzer fills the inside of the vehicle and harms the health of the members. The stack gas may be discharged out of the vehicle by connecting a pipe to the outlet of the analyzer. However, when the pipe is thin and long, it influences the measured value and, therefore, the pipe must be thick and short.
Logger	Set the USB memory and check that the following input signals are sent: ・The measured values of the five items of PG-250 (SO_2, NOx, CO, CO_2, and O_2) ・The measured value of the stack gas temperature sensor (Conduct the operations following the technical manual.)
Inclined Manometer (Manual Operation Device)	Set the inclination to be 1/20. With the differential pressure that is zero, check that the liquid level of the included liquid (ethyl alcohol) is zero to 5 cm on the scale. If the liquid is insufficient, replenish the tank with liquid. When this zero position is checked, take care to avoid any wind entering from the two inlets.
Automated Dust Sampler	After turning this sampler ON, check the display on the screen. Check that there is sufficient printer paper. Conduct zero adjustment with the differential pressure that is zero.
All Devices	When all the devices are used, the power used may exceed the power source capacity and the breakers may drop depending on the place. Complement the electric power by obtaining another power source from a neighboring house or using a power generator.

8.4.2 Leak Check on Pipes

As described in Item 8.3, the devices are connected to each other using many joint pipes. If a joint pipe is decoupled or has a hole, normal measurement cannot be conducted because the room atmosphere enters through the decoupled portion or the hole.

After connecting the pipes, the pipes must be checked to confirm that no leakage exists, according to the following method:

8.4.2.1 Moisture Line and Dust Line

Conduct the leak check according to the following procedure:

① Operate the pump (an arbitrary speed may be employed).

② Check that the gauge of the gas meter rotates (adjust the rotation speed to a proper speed using the flow regulating valve of the pump).

③ Pull out the end of the pipe on the stack side from the sampling probe and close the tip of the tube using a finger.

④ Observe the gauge of the gas meter. When no leak exists in the pipe, the rotation gradually slows and finally stops.

⑤ If the rotation does not stop, take off the pipe joint starting with the pipe joint closer to the pump and repeat the checks in ③④. Find the position of the leakage and repair the leakage.

The suction flow of the dust sampling pump is large and the rotation of the gauge usually stops shortly after the pump starts suctioning. In contrast, the flow of the moisture pump is relatively small and, therefore, it takes time to remove the air from the pipe. Therefore, be prepared to wait longer than estimated. Somewhat increasing the flow using the regulating valve results in a shorter time to suction the air.

However, when the trap bottle is a plastic bottle, the bottle is gradually crushed as the inside of the pipe becomes a vacuum. It is better to check the leak without the trap bottle not to break the trap bottle. To check the leakage of only the trap bottle, suck on the bottle.

It is necessary to take care when the leak check is conducted on the automated dust sampling devices. This leak check is described in 10.22.

Fig. 8-17 Leak Check on Pipes

8.4.2.2 Line for Gas Components

Install the gas meter downstream of the suction pump and conduct checks according to the same method as that described in 8.4.1.

8.4.3 Measurement of Duct Diameter and Flange Length, and Calculation of Measurement Points

For the gas speed measurement and the dust sampling, calculation must be conducted to determine at which point the stack gas and the dust are collected in the cross section of the duct for each facility. The figure of the image below shows the case where the cross sectional shape of the duct is a circle.

As the gas speed differs depending on the position in the duct, in order to obtain a representative value as one duct, plural measurement points are usually provided in the cross section of the duct. The measurement points are increased as the diameter becomes larger. See the technical manual for the method of calculating the positions of the sampling points (the black points in Fig. 8-14 below).

When the dust sampling probe and the Pitot tubes are inserted into the duct, adjust the length of the insertion of the probes such that the ends of these probes are placed at these positions.

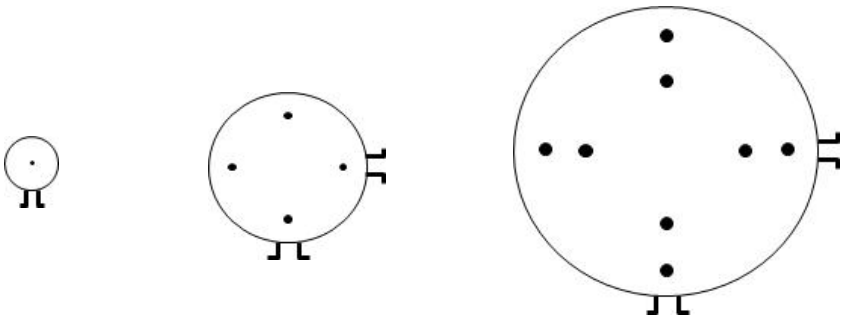


Fig. 8-18 Positions of Measurement Points in Cross Section of Duct (for Circular Duct)

Go to the measurement hole and wear a mask and protective goggles. Take care not to fall or drop anything.

Take off the lid by rewinding the bolt screws in the flange portion. There are cases where the pressure in the duct is higher or lower than the atmospheric pressure. When the pressure in the duct is higher, the stack gas may blast out into the face when the lid is taken off. Therefore, take care when the lid is taken off. For measurement holes that have not been used for a long time, dust accumulates on the flange. In an extreme case, the dust closes the hole. Remove the dust using pipes, etc., and clean the hole.

Measure the size of the inner diameter of the duct using a relatively long pipe. When the duct is circular, measure the size by inserting the pipe deep into the hole as shown in the photos below. Measure the length of the flange. Based on these measured values, calculate the positions of the measurement points by manual calculation according to the technical manual and record the results in the recording paper sheet.

Fig. 8-19 Opening of the Measurement Hole and Cleaning Thereof

Fig. 8-20 Measurement of Size of Measurement Hole

8.4.4 Start-up of PC, Preparation of Calculation Sheet, etc.

Start up the notebook PC and open the Excel calculation sheet dedicated to the stack gas measurement. Input all of the information obtained in the interview with the boiler operators, the measurement results of the duct size, etc.

Measure the atmospheric pressure and input the result into the calculation sheet.

9. On-site Measurement Work 1 (For Manual Operation Equipment)

As shown in 6.1.1, preliminary measurement is required for stack gas measurement with manual operation equipment before dust sampling. A lot of data obtained through this preliminary measurement will be used for calculations to determine the control conditions of the manual type dust sampler for smooth dust sampling after the preliminary measurement.

9.1 Preliminary Measurement

After installing necessary equipment on the stack side and the monitor side after confirming they operate normally, start measurement of the temperature, flow speed and moisture step by step.

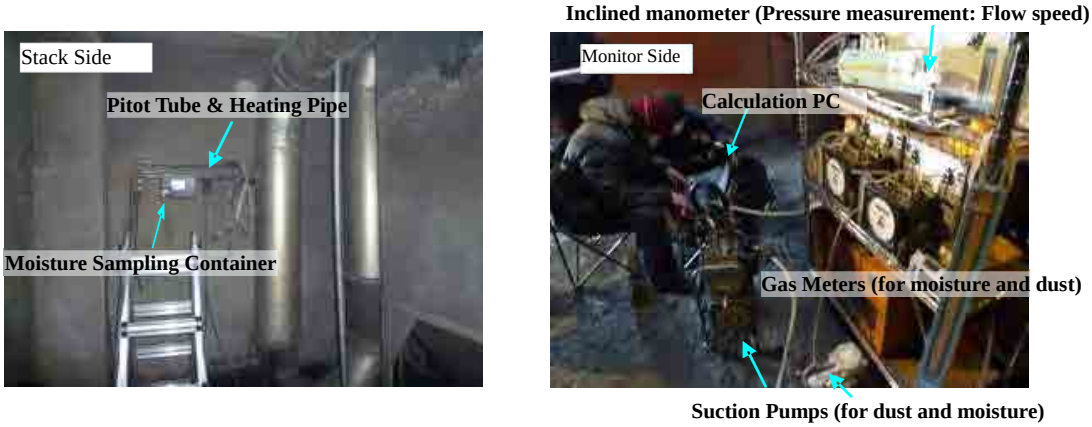


Figure 9-1 Measurement at the HOB Site

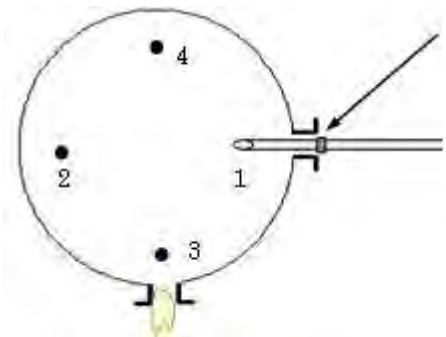
9.1.1 Measurement of the Temperature (Common to Manual and Automatic Equipment)

Measure the flue gas temperature in the duct with the equipment specified in 8.3.1.1. After observing the condition around one minute, read an approximate average value and write it down on the record sheet. The head of the Type K thermocouple may be located in any place inside the duct. However, take care for the tip not to be contact with the internal wall of the duct.

9.1.2 Measurement of the Flow speed (Manual)

The theory of flow speed measurement is specified in the technical manual.

The following is a conceptual illustration for measurement of the flow rate at the four points in total in the duct. The tip of the Pitot tube is placed at the first point to measure the flow speed.



Insert the Pitot tube properly so that its tip may be located exactly at the first measuring point.
For this purpose, provide a tape marker at this position of the Pitot tube so that one can discern it when viewed from outside.
This position as a place of enrolling a adhesive tape should be determined beforehand, as calculated at 8.4.3.
The second point and subsequent points also are marked with adhesive tape as position reference.

Figure 9-2 Positions of the Pitot Tube for Measurement of the Flow Rate

At the tip of the Pitot tube, there are two apertures: the one facing to the flow of flue gas is called the total pressure aperture, while the other is called the static pressure aperture. The total pressure aperture must be directed squarely to the flow of flue gas (the angular tolerance is ±5°).

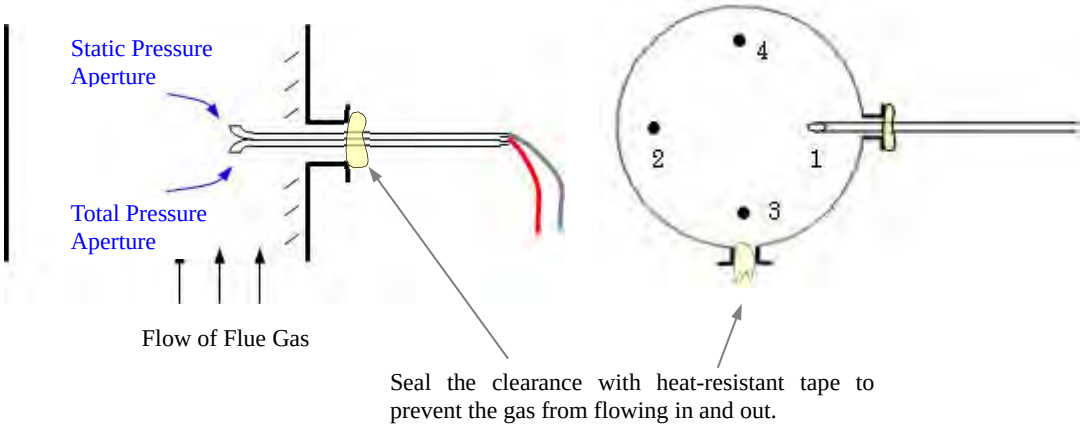


Figure 9-3 Measurement of the Flow Rate (Side View)

Figure 9-4 Measurement of the Flow Rate (Sectional View)

Measure the flow speed, following the procedure below. Write down the angle of the manometer (such as 1/20) and the pressure value measured at each point (marked on the scale of the inclined manometer) on the record sheet.

(1) Read the zero point of the inclined manometer.

Before inserting the Pitot tube into the duct, put the tip of the Pitot tube into a bag (to prevent it from being affected by a wind), and check the reading under the condition that the same atmospheric pressure is applied to the two apertures. That is, read the scale without differential pressure.

(2) Read the dynamic pressure value (Pa) and the static pressure value (kPa) at the first measuring point.

In the Figures 9-3 and 9-5, a red tube is used for connection to the total pressure side, while a grey tube is used for the static pressure side. Insert the Pitot tube slowly into the duct, and set it in the measuring position.

Figure 9-5 Inclined manometer

At this time, the level of ethyl alcohol becomes turbulent due to a shock caused by a large difference between the pressure in duct and the atmospheric pressure, if any. When the difference is too large, the ethyl alcohol flies out to the glass bulb, overflowing the right edge of the scale. In this case, when introducing the Pitot tube, as a preparatory step, the red and grey tubes are pinched by hand not to produce a sharp shock. Keeping this state, set the Pitot tube just at the first reference point. Then, gradually open the plied tubes so that pressure may work on gently the inclined manometer. Not agitating the level of liquid is the cue to get a correct reading.

The value read here is equivalent to a dynamic pressure.

Then, detach the red tube (the total pressure side shown in the Figure 9-5) from the inclined manometer, and read the scale. The read value is equivalent to a static pressure. Depending on the boiler, the static pressure in duct may become positive or negative. The magnitude of pressure also differs according to the boiler.

When measuring a large positive or negative static pressure, set the angle of the inclined manometer at 1/10, 1/5, 1/3 or vertically. When the pressure is too large to measure with these inclinations, measure the value with the U-tube filled with water.

In this inclined manometer, the graduation of 10 is equivalent to 1,000Pa at the inclination of 1/10. Since the reading method used for this system is different from those in conventional products in which readings are given in millimeters, be careful not to make mistakes.

(3) Read dynamic and static pressure values at the other measuring points in the same manner as in (2).

Figure 9-6 Measurement of Flow speed

9.1.3 Measurement of Moisture Contents (Common to Manual and Automatic Equipment)

It is possible to determine the moisture concentration of the flue gas referring to the fact that the desiccant of CaCl2 included in a Shefield bottle increases its weight when absorbing the water. For details, refer to the technical manual. The measurement procedure is as follows.

(1) Take six Shefield bottles prepared for this purpose out of the storage box.

(2) Prepare an electric balance in conditioning. Place it on a flat surface inside the warm room and set it in correct regulation of level. Set the balance not to be affected by the wind.

(3) Make a zero setting for the electric balance.

(4) Weighing of Shefield bottles before use

Close the cock, and weigh each bottle. Before the measurement, completely remove any dirt and/or water adhering to the surface of the bottle with clean tissue paper.

Write down the original pre-measurement weight on the record sheet (together with the bottle number).

Figure 9-7 Weighing of the Shefield Bottles Before Use

(5) Then, connect two Shefield bottles with a silicon tube in order to store them as a set (three sets in total). When the connecting silicon tube is too long, there is a adverse possibility that the water may accumulate at the joint. When the connection tube is too short, it is easily detached. Connect the two bottles by using a tube of a proper length to reduce the connecting distance as much as possible.

(6) Installation of the Shefield Bottles

The figure below is the same as the Figure 8-11.

Set a set of Shefield bottles with their cocks closed at the measurement aperture paying attention to the direction of the bottles. Seal the clearance with heat-resistant tape.

Set a ribbon heater as closely as possible to the inlet of the bottle as shown in the figure, in order not to allow the vapor to turn to water under the effect of cold atmospheric air, before entering the bottle. Do not raise the temperature of the ribbon heater too much (the silicon tube may be burnt at an excessively high temperature).

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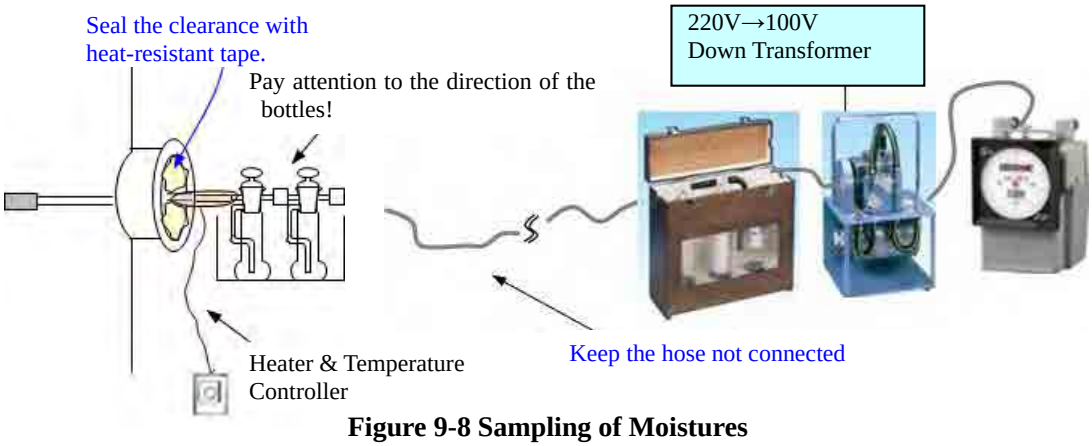


Figure 9-8 Sampling of Moistures

(7) Immediately before Starting Sampling

Before starting sampling, adjust the flow rate of the pump to approximately 1L/min. After stopping the pump, read the accumulated flow rate of the gas meter, and write it down on the record sheet as the read value before sampling. Confirm the bottle numbers of the set Shefield bottles.

(8) Timing of the Sampling

For collection of three sets of moisture samples in total, decide when to start sampling and when

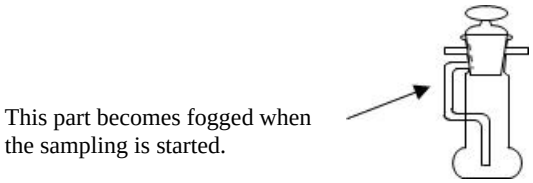
to finish appropriately, depending on the operating status of the boiler.

Usually, it takes five minutes for one set at a flow rate of approximately 1L/min, but the concentration of the coal boiler flue gas largely changes, depending on the operating condition of the boiler. To obtain a representative average, the length of time, timing and suction speed for sampling may be changed. Refer to the "Stack Gas Measurement Protocol."

(9) Start of the Sampling

Before starting the sampling, attach the detached hose. Open the two cocks of the Shefield bottles by turning them to the open side (be careful to turn them to the right direction). Soon after the communication between the stack side and the monitor side, turn on the pump and start sampling. Use a walky-talky for smooth communication between the two sides, when needed.

When the sampling is started, water vapor goes into the bent tube of the Shefield bottle, making the inside of the tube fogged. Be sure to confirm this phenomenon.



Measure the rotation time of the gas meter, and confirm that the suction rate is around 1L/min (the rate may be lower than this for a longer suction time).

(10) During the Sampling

Confirm that the sampling is going on smoothly with water drops adhering to the inside of the Shefield bottle. In addition, check that water vapor does not become water before going into the bottle due to the misalignment of the ribbon heater wrapped around the tube. If the heater is misaligned, wrap it properly. Read the temperature of the gas meter, and write it down on the record sheet. Check the rotational speed of the gas meter from time to time in order to confirm that the rate does not decline (if it has declined, clogging or leakage may be caused).

(11) End of the Sampling

Stop the pump when the scheduled closing time comes. Close the cocks of the Shefield bottles, and remove the first set of bottles for recovery. Take the reading of the gas meter, and write it down on the record sheet as the post-sampling value.

(12) Post-weighing of the Shefield Bottles

Completely remove any dust and/or moisture on the surface of the first set of recovered bottles with tissue paper. Then, weigh it with the electric balance, and write down its weight on the record sheet.

(13) Moisture Sampling for the Second and Third Sets

After finishing the sampling with the first set at (11), repeat the above steps from (6) through (12) to collect data with the second and third sets. Calculate the moisture concentration by using a dedicated dust calculation software. When the reading taken is found abnormal, an additional measurement is required with the fourth set.

9.1.4. Measurement of the Gas Component

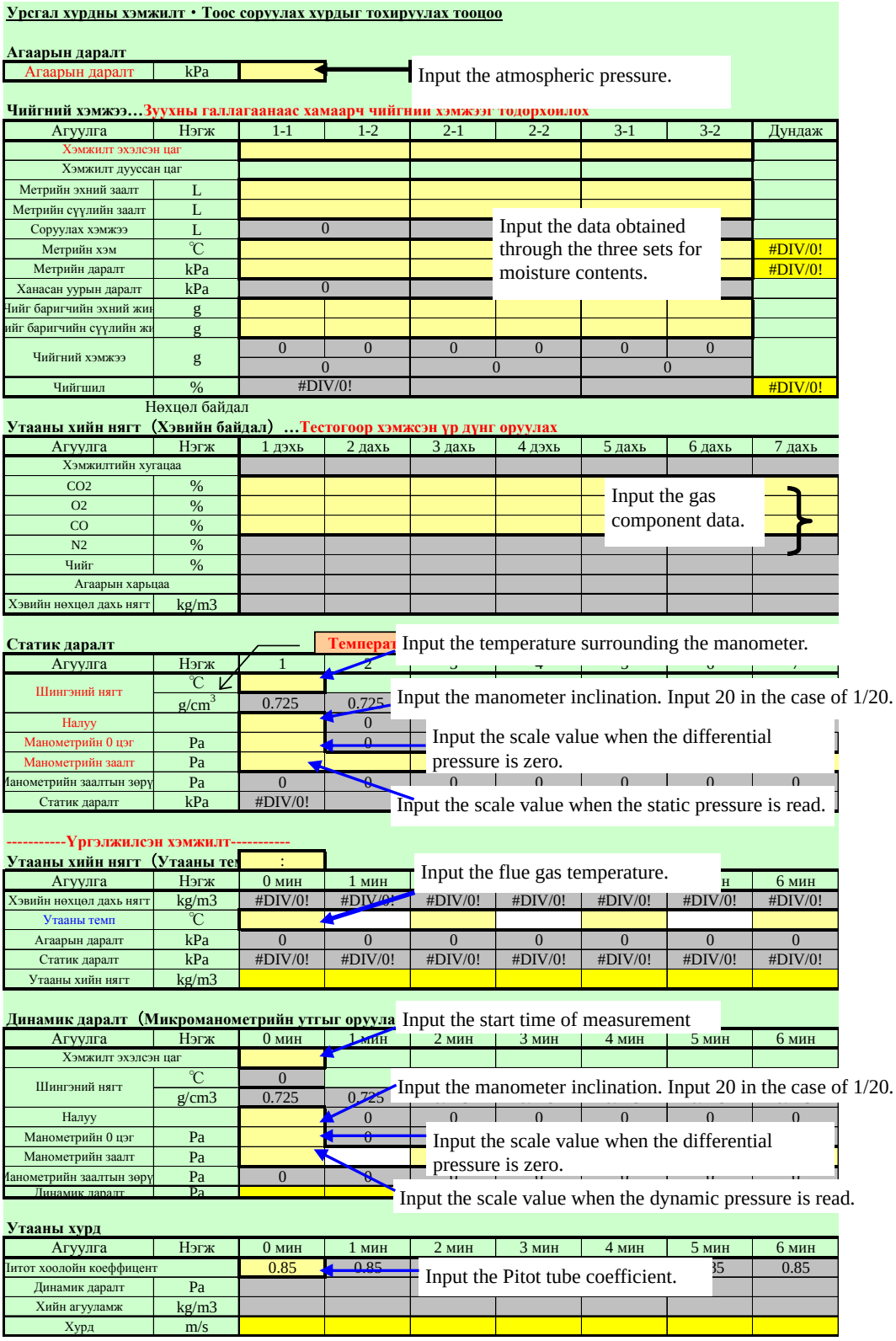
When a chemical sensor-type stack gas analyzer is used, conduct measurement, following the

sampling method and procedure specified in 4) of 8.3.2.1. Collect the samples as many as possible for better results. Be sure to collect the data on the gases if high concentrations come out after coal is fed into the boiler.

The concentration peak comes differently in time according to the measurement item. Pay attention to the sampling timing.

9.1.5 Input to the Dedicated Dust Calculation Software (Manual)

Input the data collected from 9.1.1 through 9.1.4 to the dedicated dust calculation software.



Урсгал хурдны хэмжилт • Тоос соруулах хурдыг тохируулах тооцоо

Агаарын даралт

Агаарын даралт	kPa	

Input the atmospheric pressure.

Чийгний хэмжээ…Зуухны галлагаанаас хамаарч чийгний хэмжээг тодорхойлох

Агуулга	Нэгж	1-1	1-2	2-1	2-2	3-1	3-2	Дундаж
Хэмжилт эхэлсэн цаг								
Хэмжилт дууссан цаг								
Метрийн эхний заалт	L							
Метрийн сүүлийн заалт	L							
Соруулах хэмжээ	L	0						
Метрийн хэм	℃							#DIV/0!
Метрийн даралт	kPa							#DIV/0!
Ханасан уурын даралт	kPa	0						
Чийг баригчийн эхний жин	g							
ийг баригчийн сүүлийн жи	g							
Чийгний хэмжээ	g	0	0	0	0	0	0	
		0		0		0		
Чийгшил	%	#DIV/0!						#DIV/0!

Input the data obtained through the three sets for moisture contents.

Нөхцөл байдал

Утааны хийн нягт（Хэвийн байдал）…Тестогоор хэмжсэн үр дүнг оруулах

Агуулга	Нэгж	1 дэхь	2 дахь	3 дахь	4 дэхь	5 дахь	6 дахь	7 дахь
Хэмжилтийн хугацаа								
CO2	%							
O2	%							
CO	%							
N2	%							
Чийг	%							
Агаарын харьцаа								
Хэвийн нөхцөл дахь нягт	kg/m3							

Input the gas component data.

Статик даралт

Агуулга	Нэгж	1	2
Шингэний нягт	℃		
	g/cm^3	0.725	0.725
Налуу			0
Манометрийн 0 цэг	Pa		0
Манометрийн заалт	Pa		
Манометрийн заалтын зөрү	Pa	0	0
Статик даралт	kPa	#DIV/0!	

Input the temperature surrounding the manometer.

Input the manometer inclination. Input 20 in the case of 1/20.

Input the scale value when the differential pressure is zero.

Input the scale value when the static pressure is read.

----------Үргэлжилсэн хэмжилт----------

Утааны хийн нягт（Утааны тем

Агуулга	Нэгж	0 мин	1 мин	6 мин
Хэвийн нөхцөл дахь нягт	kg/m3	#DIV/0!	#DIV/0!	#DIV/0!
Утааны темп	℃			
Агаарын даралт	kPa	0	0	0
Статик даралт	kPa	#DIV/0!	#DIV/0!	#DIV/0!
Утааны хийн нягт	kg/m3			

Input the flue gas temperature.

Динамик даралт（Микроманометрийн утгыг оруулна

Агуулга	Нэгж	0 мин	1 мин	6 мин
Хэмжилт эхэлсэн цаг				
Шингэний нягт	℃	0		
	g/cm3	0.725	0.725	
Налуу			0	0
Манометрийн 0 цэг	Pa		0	
Манометрийн заалт	Pa			
Манометрийн заалтын зөрү	Pa	0	0	
Динамик даралт	Pa			

Input the start time of measurement

Input the manometer inclination. Input 20 in the case of 1/20.

Input the scale value when the differential pressure is zero.

Input the scale value when the dynamic pressure is read.

Утааны хурд

Агуулга	Нэгж	0 мин	1 мин	6 мин
итот хоолойн коэффицент		0.85	0.85	0.85
Динамик даралт	Pa			
Хийн агууламж	kg/m3			
Хурд	m/s			

Input the Pitot tube coefficient.

Яндангийн хэлбэ	1	○:1, □:2
Дундаж хурд	#DIV/0!	(m/s)
Хөндлөн огтлол	0.000	(m^2)
Утааны темп	130	(℃)
Статик даралт	#DIV/0!	(kPa)
йгтэй утааны хэм	#DIV/0!	(m^3/h)
урай утааны хэм	#DIV/0!	(m^3/h)

Дугуй хэлбэртэй яндан		Дөрвөнжин хэлбэрийн яндан	
Диаметр (mm)		гүн (mm)	
Хөндлөн огтлол	0.00	өргөн (mm)	
Филанзны урт(mm)		хөндлөн огтлол	

Input the data on the stack shape & size and the flange size.

Figure 9-9 Dedicated Dust Calculation Software (For Manual Equipment)

9.2 Recording of the Fed Coals and the Operations of the Boiler

The boiler operator operates the coal boiler, anticipating the demand for hot water of that day. The properties of the flue gas are influenced by his operations such as feeding coal, scraping out ashes, removing clinker, and turning on/off the fan.

Start recording these operations, preferably about one hour before the start of the dust sampling (after starting the measurement of the gas component). Accordingly, it would be better to secure a dedicated recorder for recording, who observes the operations of the boiler operator. In addition, the quantity and the color of the flue gas discharged from the stack should be recorded.

Used for a calculation of the emission coefficient, these records are also very useful when you determine the reported value, which is calculated based on the organized data, is valid or not.

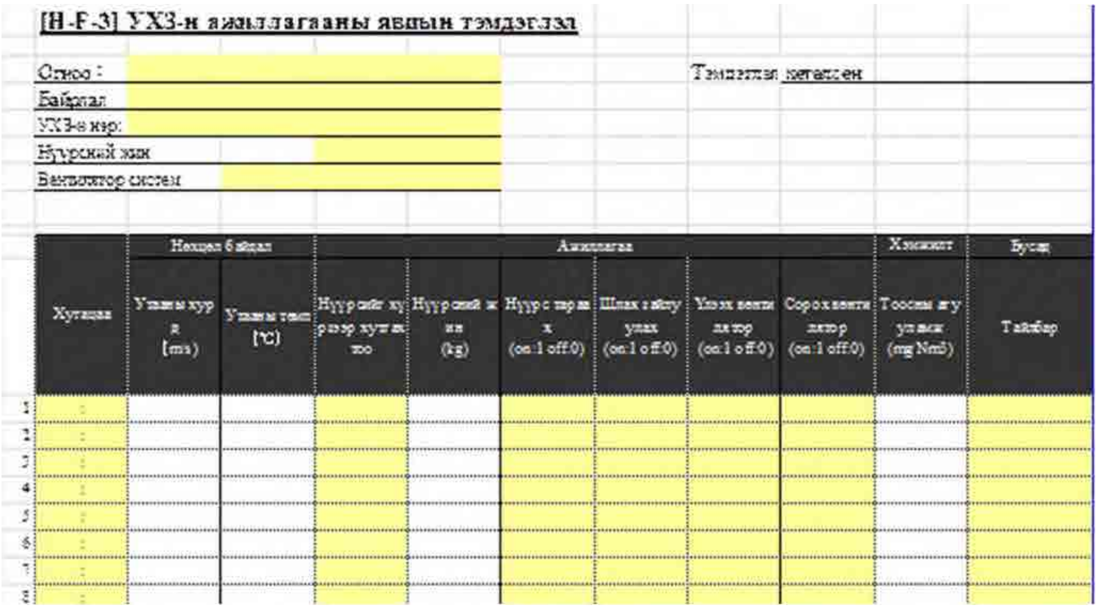


Figure 9-10 Boiler Operation Recording Sheet

9.3 Dust Sampling (Manual)

Capture the dust on the cylindrical filter, and determine the weight of the captured dust by using the difference between the weight of the cylindrical before sampling and after sampling. This is a method of obtaining a dust concentration from the total volume of gases sampled which are determined by a gas meter. Adopt the isokinetic sampling method enables to capture the dust particles as precisely as possible. For details of the approach, refer to the technical manual.

Follow the procedure below:

(1) Calculate the isokinetic sampling speed with the dedicated dust calculation software.

Open the sheet recording the inputted preliminary measurement results in Section 9.1. For calculation of an isokinetic suction speed, it is necessary to determine the inner diameter of the nozzle attached to the sampling probe first. There are a total of nine nozzles (inner diameters: 4, 6, 8, 10, 12, 14, 16, 18 and 20mm) in the nozzle box.

Figure 9-11 Dust Sampling Nozzles and Filter Holder

The size of nozzle to be used is determined based on the following conditions.

Table 9-1 How to Choose a Dust Sampling Nozzle

No.	Requirements for selection of a nozzle
1	The isokinetic sampling speed is calculated after inputting the selected nozzle inner diameter into the dedicated dust calculation software. This speed must not exceed approximately 25L/min.
2	Choose the nozzle with the largest diameter, satisfying the above.
3	It is acceptable to choose the nozzle with a smaller diameter than that of Item 2 when the sampling time will be extended due to an expected lower dust concentration.

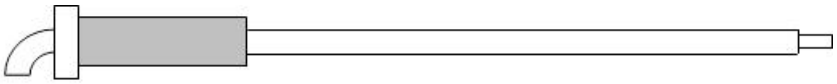
Агуулга	Нэгж	0 мин
Хошууны диаметр	mm	16
Хийн урсгал хурд	m/s	2.71
Чийгний хэмжээ	%	9.84
Метрийн темп	℃	7
Утааны темп	℃	128
Агаарын даралт	kPa	87.7
Статик даралт	kPa	0.001
Метрийн даралт	kPa	0.04
Ханасан уурын даралт	kPa	0
Соруулах хэмжээ	L/min	20.57
Соруулах хурд	sec/L	2.92

According to the above table, the nozzle of 16mm is selected with a calculated suction flow

rate of 20.57L/min.

(2) Take out a new cylindrical filter having a smaller number from the storage case containing filter paper cylinders already weighed, and fix it to the holder. Make adjustment so that the bottom of the filter paper does not contact with the filter holder bottom. Attach the nozzle with a selected inner diameter.

Make sure to place the packing, and tighten the nozzle with the cover ring. Connect the pipe (properly wind sealing tape to prevent leakage).



The following is a conceptual illustration for measurement of the flow rate at the four points in the duct. The tip of the sampling probe is placed at the first point to take the dust sample (the same image as that of the Pitot tube). Mark the sampling positions on the tube with tape.

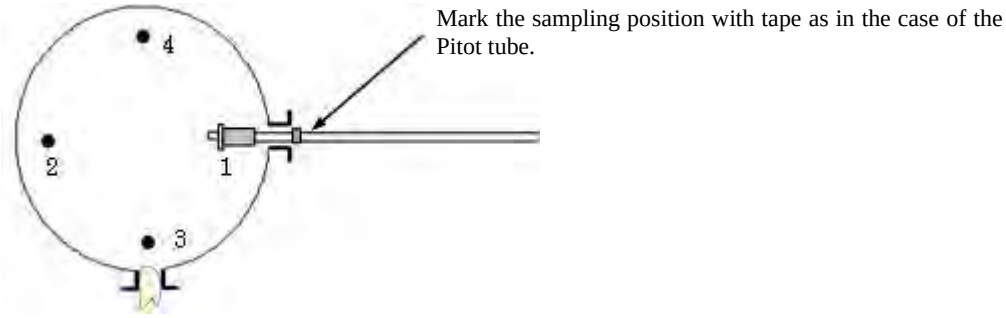


Figure 9-12 Inserting Position of the Sampling Tube with Marking

(3) Setting of the Sampling Tube

Insert the sampling probe prepared in 9.3 into the duct. As the figure below shows, the sampling probe is placed horizontally when the stack is vertical. The sampling nozzle is directed upward until the dust sampling starts. Seal the clearance with heat-resistant tape.

Insert the Pitot tube and the Type K thermocouple together with the sampling probe. Pay attention to where to set them so that they do not interfere with one another to disturb the flow. When the stack is vertical as shown in the figure, the dust sampling probe and the Pitot tube should be set side by side horizontally to prevent disturbance when the stack is placed vertically.

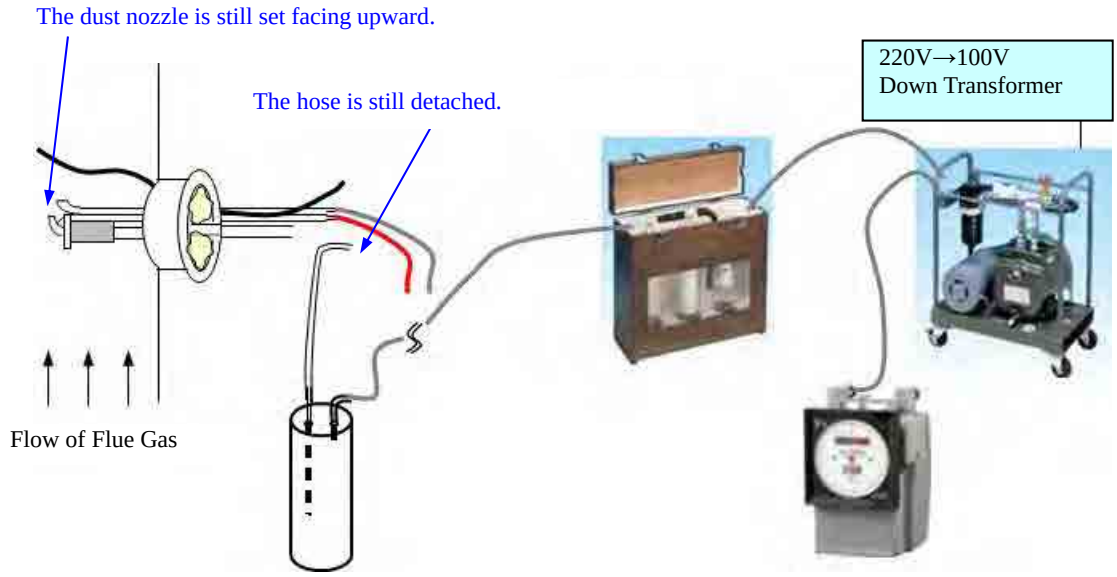


Figure 9-13 Before Dust Sampling

(4) Immediately Before Sampling

Turn on the suction pump temporarily. Adjust the flow control valve of the pump to set the suction flow rate to approximately a calculated value by measuring the rotation of the gas meter. After the adjustment, stop the suction pump. Read the accumulated flow rate of the gas meter, and write it down on the record sheet as the value read before sampling together with the number of the set filter paper cylinder.

(5) Timing of the Sampling

Although a total of three dust samples or more will be collected, the start time and the end time must be decided properly, depending on the operating status of the boiler.

The concentration of the coal boiler flue gas significantly changes, depending on the operating condition of the boiler. To obtain a representative average, give consideration to the timing of when to conduct sampling. Refer to the "Stack Gas Measurement Protocol."

(6) Start of the Sampling

Before starting the sampling, connect the hose which has been kept separated. Turn the nozzle properly to be faced with the flow of the flue gas (the angular tolerance is ±5°). Determine the insertion position of the sampling probe in accordance with the tape marked on

the sampling probe so that the sampling nozzle is properly located at the measuring point. Establish the necessary lines for the Pitot tube and the temperature sensor.

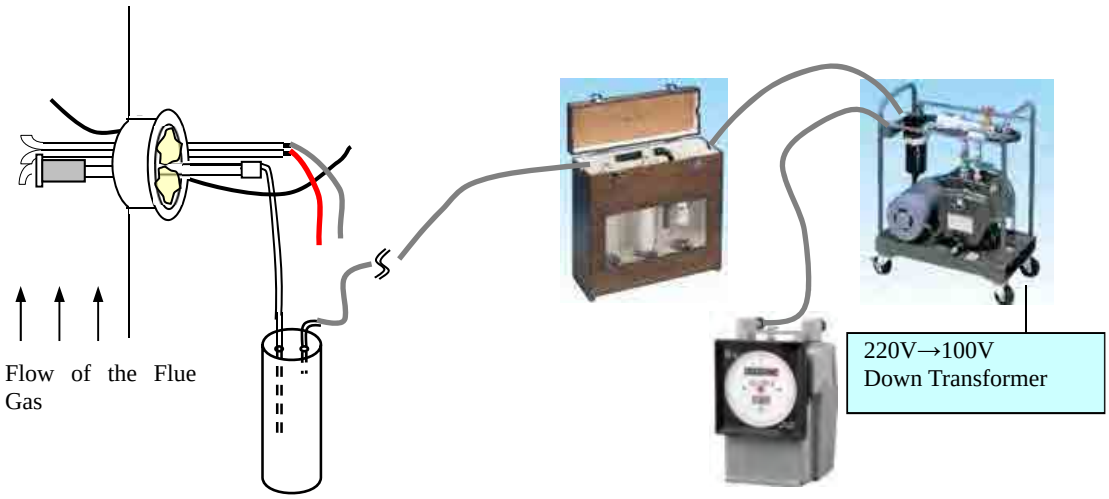


Figure 9-14 Start of the Dust Sampling

Turn on the suction pump to start sampling. Use the walky-talky for smooth communication, when needed.

After start, immediately conduct the following flow rate adjustment operations.

Table 9-2 Procedure for Adjustment of the Suction Flow Rate in Dust Sampling (Isokinetic Suction Control)

No.	Suction Flow Rate Adjustment Procedure
1	Read the current flue gas temperature with the logger, and input it into the dedicated dust calculation software (also on the record sheet).
2	Read the current dynamic pressure with the inclined manometer, and input it into the dedicated dust calculation software (also on the record sheet).
3	Read the temperature and the pressure of the gas meter, and input them into the dedicated dust calculation software (also on the record sheet).
4	Readjust the flow rate control valve again to make the flow rate close to the value automatically calculated with the dedicated dust calculation software.

(7) During the Sampling

Repeat the flow rate adjustment procedure shown in Table 9-2 at an interval of one minutes to maintain the isokinetic suction conditions. It is necessary to repeat the adjustment minutely since the suction rate declines as the cylindrical filter clogs with dust.

Check that the sampling probe is set horizontal correctly at its insertion position.

Confirm that water vapor is frozen inside the trap bottle. If it is frozen inside the piping upstream or downstream from the trap bottle, the piping is clogged and the suction pump does not work properly (the rotation of the gas meter becomes extraordinarily slow). When any clogging is found, stop the sampling temporarily to replace the clogged piping, adjust and correct the piping length before the trap bottle. Then, start the sampling again.

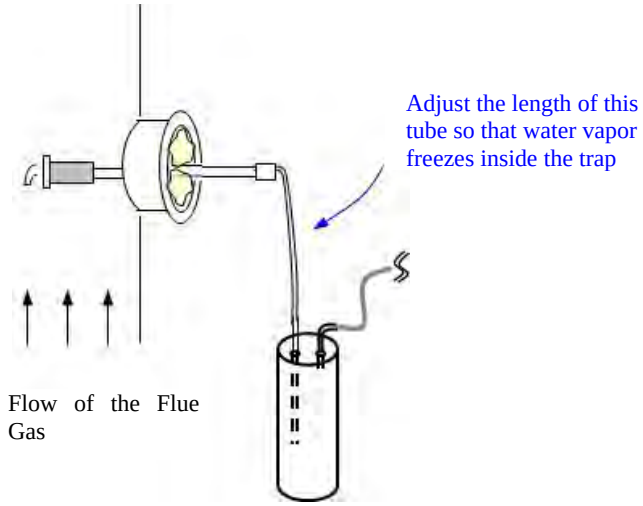


Figure 9-15 How to Fix the Tube Clogged with Freezing

(8) End of the Sampling

As a rule, conduct the flue gas sampling for 20 minutes per cylindrical filter. When the sampling time is extended further, be careful not to cause clogging in the cylindrical filter (stop sampling immediately when any clogging sign is seen).

Stop the suction pump when the sampling time ends. Pull the sampling probe out of the duct, and collect the cylindrical filter (Photo: Dedicated collecting bottle set). Read the scale of the gas meter, and write it down on the record sheet as the post-sampling value.

Figure 9-16 Collecting Filters after the Sampling

(9) Dust Collection for the Second and Third Sets

After completing the sampling at the first measuring point in (8), repeat the above steps from (1) through (8) for the sampling at the other measuring points. Collect three or more filter paper cylinders per boiler.

(10) Moving Sampling Method

The above procedure is the basic approach where one cylindrical filter is used at each measuring point. It is possible to conduct sampling at all measuring points with a single cylinder.

For example, after the ten-minute sampling at the first measuring point, displace and set the probe to the position to the second point, keeping the same cylindrical filter, and conduct another 10-minute sampling. The same 10-minute sampling process is repeated at the third and fourth points with the same filter. This is called the moving sampling method.

Needless to say, the suction flow rate must be adjusted minutely considering the flow speed differs according to each point.

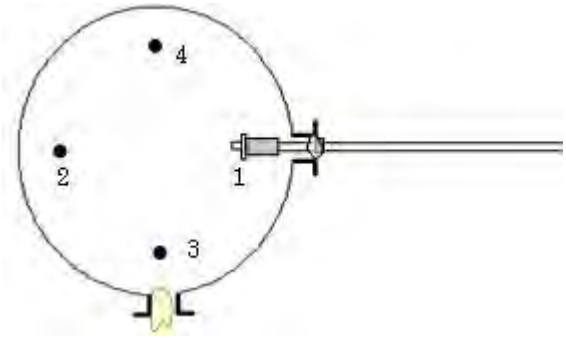


Figure 9-17 Sampling Tube and Measuring Points

However, the sampling must not be ended with the single cylinder even when using the moving sampling method. Be sure to collect at least three cylindrical filter samples per duct.

10. On-site Measuring Work 2 (with Automated Equipment)

For the use of the automated equipment, it is unnecessary to conduct a preliminary measurement required for the manual equipment as shown in the process of the Figure 6-2. Immediately after installing the necessary equipment and observing the flue gas temperature and the flow speed for a short time, you can start an automatic measurement.

The automated dust sampler has a Type K thermocouple and a Pitot tube, which are attached to its sampling probe. Its design allows to collect necessary data such as the temperature and pressure (flow speed) of the flue gas while sampling dust.

The continuous stack gas analyzer shown in 8.3.2.2 and 8.3.3 collects the gas component data. The moisture data is collected in the same manner as the manual equipment. However, the moisture sampling is conducted simultaneously with the dust sampling.

10.1 Measurement of the Gas Component (Automatic)

As specified in 2) of 8.3.2.2, the continuous stack gas analyzer must be installed and started earlier than other equipment. After warming-up the analyzer, make calibration using standard gases.

10.1.1 Calibration of the Continuous Stack Gas Analyzer

Calibration is a must to be conducted prior to the measurement with the stack gas analyzer on the day of a measurement.

After warming up the stack gas analyzer and confirming its normal operation, start collecting the necessary data with the logger.

Connect the cylinder filled with the standard gas to the standard gas inlet of the stack gas analyzer, and introduce the standard gas flow into the analyzer with the specified pressure. Adjust the sensitivity for each measurement item.

In the case of gas analyzers made in Japan, they differ from one another about how to introduce the gas into the analyzer (refer to the figures below). Never apply pressures exceeding the atmospheric pressure to the analyzer which designed to introduce the gas at atmospheric pressures.

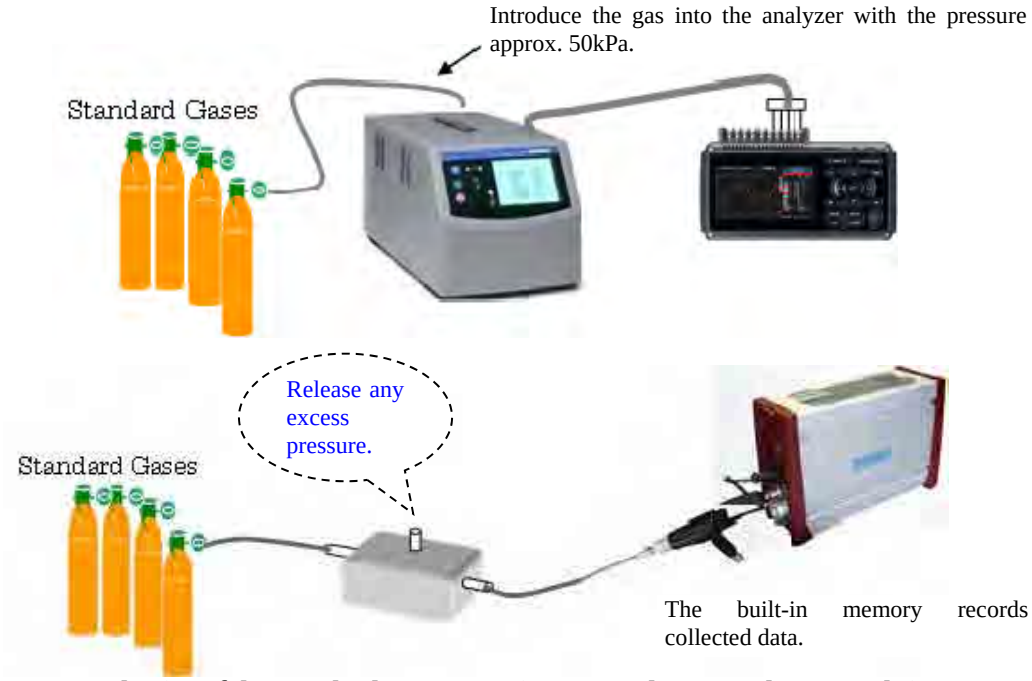


Figure 10-1 Introduction of the Standard Gas to Continuous Stack Gas Analyzers Made in Japan

The following types of standard gasses are available. Be sure to use the gasses whose validity term is guaranteed by manufacturer.

Table 10-1 Types and Concetrations of the Satndard Gasses for a Analyzer (Example)

Zero Gas	N2 Gas (Purity: 99.9999% or more)
Span Gas	SO2／N2 190ppm
	NO／N22 190ppm
	CO／N22 190ppm (for low concentration), 4% (for high concentration)
	CO2／N2 14.5%
	O2／N2 21.5%

The fundamental procedure for calibration is as follows. Conduct the span calibration following the zero calibration. It is enough to conduct these two points calibration. For the operational procedure of the equipment, refer to the technical manual.

Tbale 10-2 Calibration Procedure for a Stack Gas Analyzer

Zero Calibration	Introduce the N2 gas of a specified pressure into the analyzer through the standard gas inlet.
	Continue feeding the gas into the analyzer for one minute or more. Watching the concentration graph indicated on the logger, confirm that the indication is stabilized (in each measurement item) and the concentration is close to zero.
	Conduct the zero calibration. Do not make a too rough calibration.
	Keep the calibration coefficients on record.
Span Calibration	Introduce the standard gas of a specified pressure into the analyzer through the standard gas inlet.
	Continue feeding the gas flow into the analyzer for one minute or more. Watching the graph indicated on the logger, confirm that the indication is stabilized (in each measurement item) and the concentration is close to the level indicated on the cylinder.
	Conduct the span calibration. Do not make a calibration exceeding 2%.
	Keep the calibration coefficients on record.
	Finish the calibration. Return to the normal measurement mode.

10.1.2 Start of the Gas Component Measurement

Reconnect the piping as illustrated in 8.3.2.2 and 8.3.3 to start the flue gas measurement in accordance with the following procedure. Complete the operations up to this step while making preparations for the dust and moisture sampling equipment.

(1) Confirm that the equipment is collecting the data with the logger and the built-in memory.

(2) Start the suction pump. Confirm that the excess flue gas is sufficiently released from the manifold just behind the pump.

(3) Observe that the concentration indicated on the stack gas analyzer is approaching the concentration of the flue gas. When the indicated oxygen level is around 19%, attention is required for the possibility that the line may have leaks or be clogged.

(4) Maintain this monitoring (keep monitoring until dust and other sampling operations are completed).

(5) Watch how the concentration indicated with the logger graph changes from time to time. Carefully observe that operational changes in the boiler such as coal feeding are properly reflected in the indication.

(6) Confirm that the readings of measurement by the two measuring units for high and low concentrations are close to each other.

10.2 Preparation Work (Automatic)

Like the manual type equipment, 8.3 “Installation and Warming up of the Equipment” and 8.4 “Checks after Installation” are also required for the automated equipment operation. After finishing these steps, make preparations for the dust and moisture sampling.

10.2.1 Preparations for the Moisture Measurement

Implement the steps from (1) through (5) of 9.1.3.

10.2.2 Preparations for the Dust Sampling

For the automated dust sampler, conduct the following check operations.

1) Checking leaks from the piping

Like the manual sampler, conduct checking in accordance with 8.4.2.1, but do not connect the piping to the automatic controller main body (see the figure below), to protect the inside delicate pressure sensor from pressure shock during leak check.

For the line on the stack side, confirm that there are no leaks by sucking the line with your mouth.

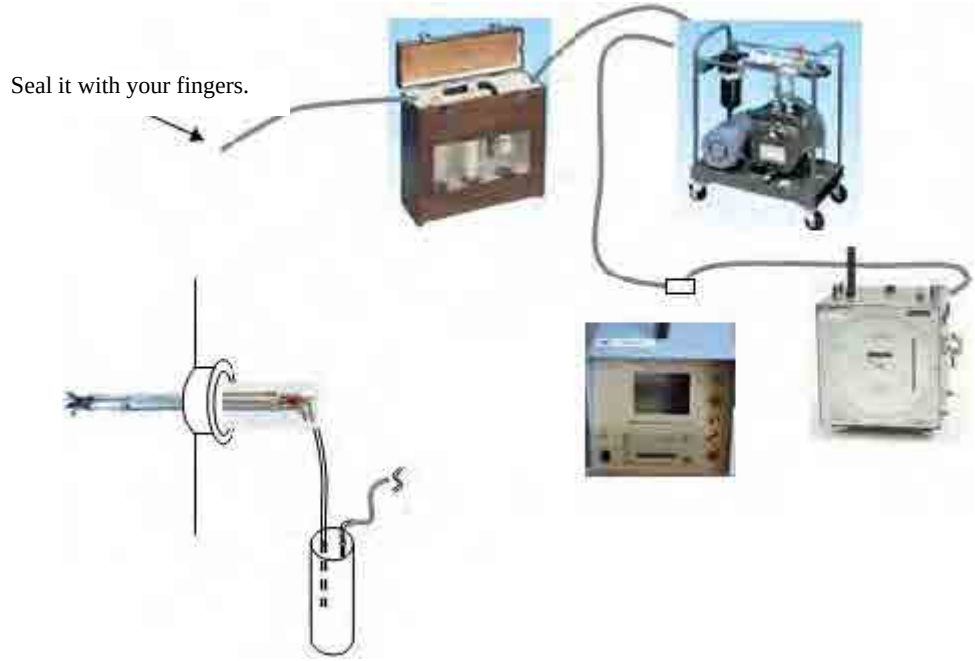


Figure 10-2 Leak Checking for the Automated Dust Sampler

2) Checks of the Controller Main Body

After turning on electricity, check in accordance with the table below.

Table 10-3 Movement Checks for the Automated Dust Sampler

Check Item	Detailed Checking
Time	Confirm that the current indicated time is correct.
Zero Adjustment for the Manometer	Remove the sampling tube and connecting pipings (in 4 colors) from the equipment back. Press the "0-ADJ" button on the front under the condition that the same pressure (atmospheric pressure) is applied to the four ports. Zero adjustment is conducted for the manometer.  Prevent these four ports from being affected by a wind. Do not seal them with your fingers (because excess pressure is applied to their inside). (For checking of the isokinetic sampler pressure sensors) After inputting 1 as the Pitot tube coefficient and 6 mm as the nozzle diameter on the screen, apply the same pressure to the red and yellow pipe. When the dynamic pressures of the two sensors are indicated as a same Pa value, the pressure sensors are normal.
Interlocking with the Suction Pump	Be sure to turn on the suction pump and manually turn the pump flow control valve almost fully opened (when much air is not fed to the main body from the pump, the flow rate control in the main body will be delayed with difficulty of operation). Confirm that the controller will automatically regulate the flow rate even if the flow control valve is manually turned to a certain position.
Printed letters of the Printer	Pull out the printer paper holder to confirm that enough paper remains. Check that the printed letters are clear and the printer starts printing at the set intervals. Also check that the necessary data is output onto the paper.

3) Confirmation of the Flue Gas Temperature and Flow Speed

Complete the connections of the equipment. Then, insert the sampling probe with no dust sampling filter into the measurement hole. Keep monitoring the flue gas pressure and temperature in the duct which are indicated on the screen of the automated dust sampler.

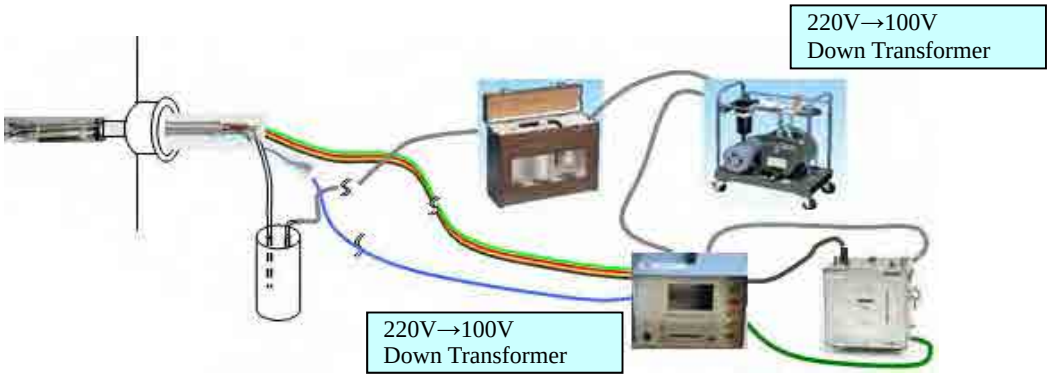


Figure 10-3 Confirmation of the Flue Gas Conditions

4) Setting of the Parameter

While checking the flue gas conditions in a simplified manner in 3), set the parameters with the controller main body. For the procedure, refer to the technical manual.

Parameter Setting	In accordance with the technical manual, conduct the "selection of the parameter and input of the values" on the screen. (Type of the fuel in use, shape of the duct, sampling method, filter attachment position, shape and material of the filter, Pitot tube coefficient, type of the gas meter, measuring method, length of the sampling time or total volume of the sampling gas, time intervals of the printer output, anticipated moisture concentration, and nozzle inner diameter)

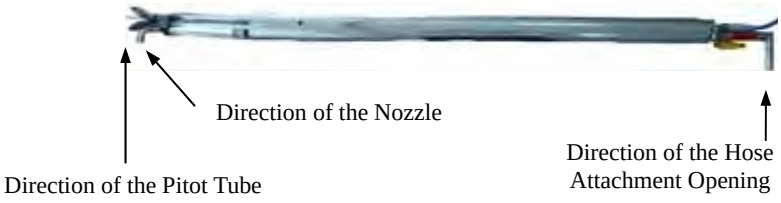
The selection criteria for a sampling nozzle diameter are the same as shown for the manual sampler.

After completing the setting, take out the sampling probe from the measurement aperture.

5) Attachment of the Filter Head

How to set the filter paper is almost the same as 9.3. Set the nozzle with the selected inner diameter.

Attach the filter head to the sampling probe to constitute a complete unit. Adjust the positions so that the Pitot tube, the dust nozzle and the suction hose attachment opening are in the same direction.



10.2.3 Assembly of the Equipment on the Stack Side

For sampling, set a sampling probe at the measurement hole. As shown in the figure below (sectional view of the duct) shows, how to set the three sampling tubes and the temperature sensor, in addition to the sampling probe for gas component under measurement. The figure below illustrates a case where the inner diameter of the duct is small and dust sampling is made at one point, in the center of the duct.

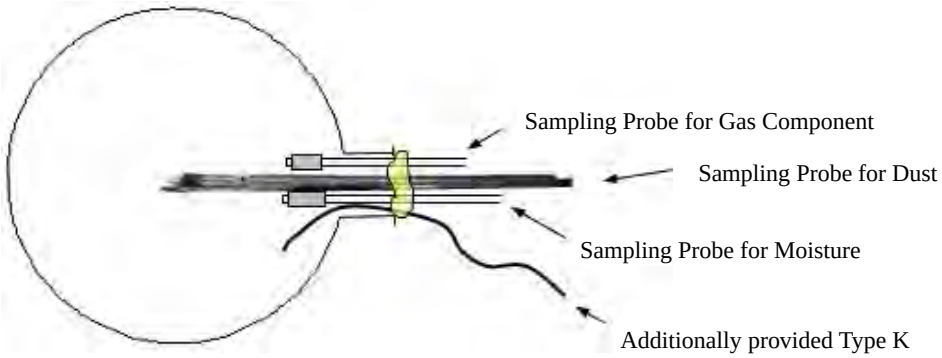


Figure 10-4 Sampling Tubes Inserted into the Measurement Hole (Duct Sectional View)

10.2.4 Immediately before Starting the Sampling

Next, complete the moisture sampling line by following the steps of (6) and (7) of 9.1.3. Read the moisture gas meter before sampling, and write it down together with the Shefield bottle numbers on the record sheet.

In addition, complete the dust sampling line as shown in the Figure 8-15 (the dust nozzle must not face the flow of the flue gas before sampling). Write down the read value of the dust gas meter before sampling, and write it down along with the number of the attached filter on the record sheet (read the value with your eyes, although the automated dust sampler automatically measures the accumulated suction volume).

Figure 10-5 Installed Equipment on the Stack Side (For the Automated Equipment)

Figure 10-6 Monitor Side Prepared for the Sampling

Like the manual equipment, confirm that the facility information record sheet and the measurement data record sheet shown in the Figure 7.2 are filled out with necessary information.

10.3 Sampling of Dust and Moisture (Automatic)

In principle, dust and moisture must be collected in the same timing and for the same length of time for the automated equipment.

10.3.1 Start of the Sampling

After confirming that the necessary lines are all connected, start the moisture and dust sampling at the same time. The main procedure is indicated in the table below.

Table 10-4 Sampling Start Procuedure for the Automated Dust Sampler

Item	Work Description
Dust Sampling	Turn the dust sampling nozzle in the same direction against the flow of the flue gas.
	Turn on the suction pump switch and the start button of the controller main body.
	Write down the sampling start time on the record sheet.
	The indication of the main body screen changes to “Under Measurement.”, Automatic control of the gas suction speed starts. The values of the “Flue Gas Dynamic Pressure Pd” and “Suction Gas Differential Pressure Vd” indicated on the screen become close to each other. When they are almost the same, the isokinetic sampling comes into effect.  Then, sampling goes on under the automatic control.
	Confirm that the indicated flue gas temperature accords with the value of the other temperature sensor indicated on the logger.
	Check the setting condition of the sampling probe on the stack side and the condition of the trap bottle again.
	Check the set parameters again.
Moisture Sampling	Same operation as the manual type equipment: Follow the step (9) of 9.1.3. However, it is possible to decrease the suction flow rate to around 0.5L/min.
	Write down the sampling start time on the record sheet.

For the continuous stack gas analyzer, watch how the concentration changes again referring to the logger graph indication.

Check that the indicated values of the measuring equipment for high concentration and for low concentration become close to each other.

10.3.2 During the Sampling

The check points for the moisture sampling are the same as (10) of 9.1.3.

The check points for the dust sampling are almost the same as (7) of 9.3. The isokinetic sampling controlled by the automated equipment is different from the manual type equipment.

As shown in Table 10-4, confirm that the dust sampling is automatically controlled under the isokinetic sampling conditions. The automated sampler prints the control and other conditions with the printer at the set intervals. Regularly check that there are no abnormalities.

Even under the automatic control, isokinetic sampling sometimes does not work. In that case, it is necessary to manually operate the flow control valve of the pump so as to return it to the position easy to control. This happens due to any extreme flue gas condition at the site such as the flow speed drastically fluctuating or due to the low flow speed, to which the controller cannot properly respond. If the suction rate extremely goes to the maximum or the minimum under the out-of-control condition, the BZ lamp lights and the buzzer sounds. In this case, operate the flow control valve immediately so as to return it to the position where the automatic control works.

10.3.3 End of the Sampling

The steps for the moisture sampling are the same as (11) and (12) of 9.1.3. Sampling of moisture contents is finished at the same time when dust sampling is complete.

When the sampling flow rate (or time) designated through the parameter setting reaches the target, the equipment automatically finishes the sampling and the stop lamp lights (but manually turn off the suction pump when the pump is plugged into a different power outlet from that of the main body).

Pull out the sampling probe from the duct, and collect the first cylindrical filter like the manual sampling. Read the gas meter, and write it down on the record sheet as the value after sampling.

10.3.4 Sampling of the Second and Third Sets

The procedure for the automated equipment is the same as that for the manual equipment. Conduct the second and third moisture samplings in the same timing as the dust sampling.

After completing the first dust sampling, repeat the above steps of “3) through 5) of 10.2.2, 10.2.3 and 10.2.4,” and start the next sampling. Use three cylindrical filters or more per boiler.

10.3.5 Moving Sampling Method

As for the moving sampling method, follow the step in (10) of 9.3.

11. Completion of the Entire Monitoring and Pullout

After collecting three samples each for dust and moisture, complete the entire monitoring, following the procedure specified in the table below. The operations which differ between the manual equipment and the automated equipment are shown separately. For the removing the equipment, bring back the equipment to the vehicle, following the installation procedure in the reverse order. Be sure to pay attention to the safety during the operation.

Table 11-1 Operations to Finish the Entire Monitoring (Automatic)

Item	Outline of the Operations	
	For the Manual Equipment	For the Automated Equipment
Gas Component Sampling	<For the Chemical Sensor-type Gas Analyzer> (1) After analyzing the sample gas, let normal air flow through the analyzer to prevent the sensor from deteriorating. The purging time differs according to the type of analyzed gas and the length of analysis time (refer to the manual). For purging, the longer the better. (2) Turn off the measuring equipment to place them in their cases. Confirm that analyzed values are output on the record sheet. (3) Pull out the sampling probes from the measurement hole, and put them in their dedicated case together with the main body.	
	<For the Continuous Stack Gas Analyzer> (1) Leave the sampling probe pulled out of the measurement hole on the floor until it gets cool. (2) Stop the suction pump. Let the atmospheric air flow through the analyzer for several minutes. (3) Complete the data recording with the logger and the memory. Then, transfer the recorded data from the logger to a USB. (4) Operate the analyzer and the logger to stop them in accordance with the technical manual. Detach the signal lines and the power cables. (5) Pipings: Purge water if there is any inside. Roll them for pickup. (6) Put back other equipment in their dedicated cases.	
Moisture Sampling	(1) Pull out the sampling probe from the measurement hole. Put back the Shefield bottles into the case. (2) Confirm that all necessary monitoring records are output on the record sheets. (3) Detach the pipings from the gas meter, the pump and other apparatuses to put them back into the shelf and the storage boxes. Be careful not to break their glass parts.	
Dust Sampling	(1) Confirm that the dust-sampling cylindrical filters are placed in the storage box.	
	(2) (None)	(2) You may turn off the power soon after the equipment finishes automatic sampling. Collect the paper sheets output from the printer (record the place and the date).
	(3) Confirm that all necessary monitoring records are output on the record sheets. (4) Put back the sampling nozzle into the case, and check that all nozzles are in place. Clean up dirty nozzles, if any. (5) Remove any dust from the surface of the detached sampling probe to put it back into the dedicated case. (6) When the wet type gas meter is used, take out antifreeze from the inside (to return it into the container). (7) Put back the gas meter and other apparatuses into their dedicated cases. (8) Pipings: Remove water if there is any inside. Roll them for pickup.	
Others	(1) Confirm the on-site data documents such as “record sheets, memories collecting data, and output paper sheets from the printer,” and take them back to the office in one lump. (2) Take away the pipes, the thermocouple, the sampling tube and others from the measurement hole. Fix the cover placed on the hole with screws.	

	(3) Return the provided power cables and any other articles to the facility, if any. (4) Load all equipment you brought to the site onto the vehicle. Check each of them for confirmation so that nothing is left behind. (5) Clean up the monitoring site, and bring back all refuse to the office. (6) Report to the facility manager that the monitoring is completed, and go back to the office. (7) After returning to the office, unload the equipment and samples to place them in the equipment room on that day.

Figure 11-1 Pullout Scenes

12. Storage of the Equipment and Samples

When returning to the equipment room, complete the following operations on that day.

(1) Put back the equipment into the shelf or in their original places.

Conduct maintenance for necessary equipment on the same day if it is minor work. If their maintenance requires much time, mention it in a notebook so that the maintenance work will be done at a later date.

Figure 12-1 Storage of Equipment

(2) Put the record sheets and the printer record sheets of the automated dust sampler you brought back to the office into the dedicated file.

(3) Transfer the cylindrical filters for dust sampling from the storage container to the desiccator (check the post-measurement weight at a later date, following the procedure specified in Table 7-3). For the data reduction procedure, refer to the technical manual.

(4) Tell the superior that all work is completed, and this is the end of all operation.

6 Stack Gas Measurement Procedure for Ger Stoves

Capacity Development Project
for
Air Quality Control in Ulaanbaatar City, Mongolia

Stack Gas Monitoring Guideline
for
Ger Stove

November 2012

Contents

1. How to Use This Book

The JICA Project' Capacity Development Project for Air Quality Control in Ulaanbaatar City' measured air pollutants in discharged gas from boilers during two winter seasons in Ulaanbaatar City, and obtained representative data of their concentration and emission factors. The instructions and work procedures are shown in this guideline based on actual field monitoring for measurement of air pollutants emitted from a stationary source.

This Ger Stove Stack Gas Monitoring Guideline is one of three Guidelines prepared for three typical pollution sources: 'Coal Power Plant, Heat Only Boiler (HOB) and Ger Stove.'

This book shows the entire stack gas monitoring schedule for a stove in Chapter 6, and details of task procedures or instructions are shown in from Chapter 7 to Chapter 12 in order.

There are many complicated task procedures in this method; however, conventional measurement techniques are used. The details of task procedures such as the equipment operation procedures are separately summarized in other technical manuals as a reference, because the details of every procedure are not necessary all together in one book. The measurement rules commonly applied for three Stack Gas Guidelines are prepared as the 'Stack Gas Monitoring Protocol' shown below.

Table 1-1 Technical Reference Materials

No.	Material Name
1	Stack Gas Monitoring Protocol
2	Installation Procedure of Measurement Hole on a Chimney
3	Wet Sampling/Analysis Procedure for Gases
4	Moisture Measurement (Technical Manual)
5	Temperature Measurement (Technical Manual)
6	Flow Rate Measurement (Technical Manual)
7	Automated Stack Gas Analyzer TESTO (Technical Manual)
8	Automated Stack Gas Analyzer PG (Technical Manual)
9	Automated Stack Gas Analyzer HT-3000 (Technical Manual)
10	Automated Isokinetic Dust Sampler (Technical Manual)
11	Data Reduction Procedure (Technical Manual)

2. Purpose of Stack Gas Monitoring

In Mongolia, hot water necessary for people's daily living and their industrial activities is produced mainly by burning coal in thermal power plants, small boilers (HOB, CFWH), and household stoves.

The thermal power plants constitute the core of the large-scale hot water supply network for the central part of the city. In areas without the supply of this hot water, each city block is provided with a small boiler and forms a zonal heating system using the boiler. Thereby, the hot water is supplied to ordinary houses and public facilities (schools, hospitals, etc.) in the vicinity of the small boiler. In the surrounding areas and some isolated areas that do not even have this type of hot water supply network, coal stoves are used in ordinary houses and Ger.

Air pollution becomes heavy in winter and is considered to be generated mainly by the combustion of coal in these fixed generation sources. In order to reduce the pollution, it is necessary to regularly measure the amount of air pollutants discharged from the fixed discharge sources.

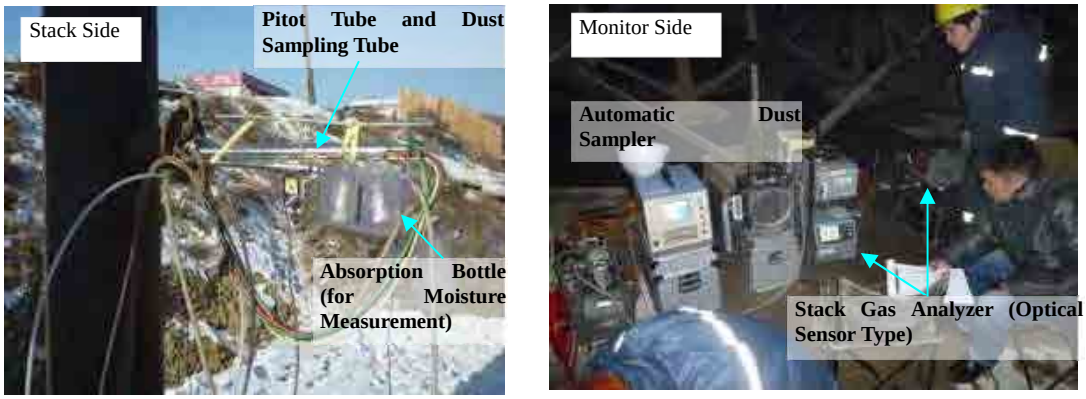


Fig. 2-1 Stack Gas Monitoring

3. Features of Monitored Stove

Monitoring target is the Ger stove, which is the popular heating source for cocking and house heating for domestic use. It is indispensable sole heat source especially in the isolated area where there is no local heating system from thermal power plant or HOBs.

People always use Ger stove when it is used for cooking. During the late of chilly September through the beginning of June in late spring, it is used as house heating source around 8 or more months.

The quality of using coal for Ger stove is generally low, while comparatively high quality coal is used for thermal power plants. Low quality coal is the moderate price fuel much cheaper than electricity for the masses.

There are at least two types of Ger stoves, so called traditional type (old-fashioned stove) and Turkish type, are manufactured in Mongolia. The traditional type stove that has been ever used for the cooking or wall stove in home can provide strong heating power, but is not convenient to use as house heating, because it burnt out in two or three hours. Some models of traditional type have being developed to utilize the produced heat more effectively by domestic stove maker.

Compared to traditional stove, Turkish type Ger stove is designed to keep burning longer time when burning same weight of coal, since it can adjust the entering air flow rate finer. Therefore, Turkish type is generally used for house heating source, but for cooking use due to its week power of heat. Both type stoves are the complementary pair. Popularization of turkey stove has being promoted widely, homes using both types of stoves have increased these days.

Many kind of carbonized coal briquettes (coke) are on the market in recent Ulaanbaatar City, but the quality of them is uneven, the pollutants in flue gas from them vary widely in concentration.

3.1 Constituent Parts of a Stove

As to only the gas line, a stove consists of the following main parts:

Table 3-1 Major Components of Stove

Section	Major Component
Main Body of Stove	Furnace, fire grate, heat exchanger tube, coal feed inlet, outlet for ash. There is a unique type of stove, which attach the firebrick on inner wall to raise the heat radiation effect.
Draft Fans	None
Gas Treatment Unit	
Duct/Chimney	Thin iron pipe (the heat insulator are usually used to wind it around the chimney at ordinary house).

Fig. 3-3 Type of HOB

3.2 Structural Factors Influencing Flue Gas Conditions

Table: 3-2 shows the major operational factors that influence the flue gas measurement value. The 'structural factors' in this table correspond to the contents in Section 3.1. Both structural and operational conditions influence the amount of discharged pollutants.

Table 3-2 Factors Influencing the Flue Gas Conditions

	Structural Factors	Operating Factors
Coal Feeding	Automated or manual type	Time interval, amount (related to hot water demands), size, kind and components of coal.
Ventilation	Natural, forced	adjustment of damper travel
Gas Treatment Unit	None	-
Others	Stove types	Raking for ash removal and clinker discharging

4. Measured Items and Measuring Equipment

'Measurement Items and Methods' and 'Outline of Measurement Equipment' are respectively described in Chapter 4.2 and Chapter 4.3.

The equipment for gas analysis and dust sampling should be chosen according to its merits, as shown below.

4.1 Differences between Two Types of Gas Sensors

The upper half of the following table shows the differences between two types of gas sensor methods. To evaluate the measurement accuracy and reliability of the values reported for each method, the lower half of the table gives one of the three grades: 'high, moderate, and low.'

Table 4-1 Performance Difference between Stack Gas Analyzers

Sensor Type of Stack Gas Analyzer		Chemical Sensor	Optical Sensor
Feature	Concentration range	Covers both low and high concentration range.	
	Deterioration of sensor	Easy deterioration in high concentration interference gas.	Robust
	Measurable time range in continuous monitoring	A few minutes especially in high concentration CO gas	Long time range (hours) in every gas condition
Data Collection	Total number of data and sampling timing	Three data for a stove at random timing	Hundreds of data for a stove Every 10 seconds during the whole sampling time
Calculation of Reporting Value	Calculation of the average concentration	Average of few data	Averaging hundreds of data
	Calculation of the average concentration (after O_2 conversion)	Unsatisfactory representative result due to few sampled O_2 data	Good representative result based on hundreds of sampled O_2 data
Quality of Measurement Accuracy	At calibration	Moderate (Sensor sensitivity degrades gradually during several months by being affected by interference from sample gases.)	High
	Appropriateness of the gas sampling method	High	High
Validity of Sampling Condition Chosen	Setting of the measurement timing	Low	High
	Sampling time period	Low	High
Reliability of Report Value (Gas Concentration)	Calculation accuracy of O_2 conversion value	Low	High

Chemical Sensor Type

Optical Sensor Type

Figure 4-1 Stack Gas Analyzers Used

4.2 Differences between Two Types of Dust Sampling Equipment

Table 4-2 Differences in Equipment Performance/Use and Data Calculation for Dust Sampling

Type of Dust Sampling Equipment		Manual Type	Automatic Type
Use	Isokinetic sampling control	Read out the gas condition every two seconds, and adjust the sampling speed manually	Continuous automatic control
	Total number of data sampling timing	Three samples for a stove, taking around 20 minutes for a dust sample. The sample timing and time length are to be determined by actual operative information of a target stove.	
Calculation of Reporting Value	Calculation of average concentration	Arithmetic mean of three data	Time-weighted average concentration of three data
	Calculation of average concentration (after O_2 conversion)	Unsatisfactory representative result due to few (three) sampled O_2 data	Good representative result based on hundreds of sampled O2 data
Operability	Quickness of control	Moderate	High
	Accuracy of control	Moderate	High
Validity of Sampling Condition Chosen	Start timing	High	High
	Sampling period	High	High
Reliability of Value for Reporting (Dust Concentration)	Calculation accuracy of O_2 conversion value	Middle	High

Manual Type

Automatic Type

Fig. 4-2 Dust Samplers Used

4.3 Features of Equipment for Measurement in Winter

Special care should be taken to prepare equipment for out-door monitoring in Ulaanbaatar City because the temperature can fall to minus 30 or 40 degrees in a severe winter season.

Table 4-3 Freeze Prevention for Monitoring Equipment

No.	Name	Method
1	Inclined Manometer	Use an anti-freeze solution as the inner liquid such as ethyl alcohol.
2	Gas Meter	Use the dry type gas meter. If the wet type is used, it will require anti-freeze solution.
3	Power Cable	Use a cold-resistance power cable to prevent short circuit problems due to a hard frozen cable malfunctioning.
4	Gas Sampling Tubes (Connection Cables between Chimney Side and Analyzer Side)	Use a silicon braid hose for moisture and dust measurement. A Teflon tube must be used for gas component measurement.
5	Trap Box	Use plastic bottles to prevent the moisture in the sample gas from concentrating and freezing inside the sampling tube for gas or dust measurement use.
7	Heat Resistant Material	Wrap the sampling tube with insulation piping.

5. Technicians for Measurement

The technicians to perform the stack gas measurement must satisfy the following requirements:

Table 5-1 Qualification for Stack Gas Monitoring Technician

No.	Requirement
<As the capacity of a monitoring team>	
1	The team must be the owner of stack monitoring equipment as shown in Chapter 4, or should be an organization that has the capacity to borrow the equipment.
2	Owner of a laboratory, or the person who has the capacity to use a laboratory as a work place for weighing samples or maintaining equipment.
3	Capable of procuring a van to carry the equipment to the monitoring site.
4	Capacity to assign two or more experienced technicians for the stack monitoring work on a boiler. (Beginners must not be counted as experienced staff members.)
5	Self-management capacity to generate a report voluntarily and honestly when problems occur with the monitoring equipment during its use. Capacity to pay to fix malfunctioning equipment.
<Personal Qualification>	
1	A person who participated in the training course of stack gas monitoring in a JICA project, or has rich experience of performing actual monitoring in power plants or on HOBs.
2	More than 30 times of monitoring experience on site
3	Capability to operate the isokinetic dust sampling
4	A high level of understanding to use the dedicated dust calculation software.

6. Monitoring Steps

An overview of the stove stack gas monitoring steps for the stove will be described. The monitoring steps on the day are detailed and will be described in Section 6.1.

Table 6.1 Monitoring Steps and Contents of Monitoring

No.	Time	Contents
1.	Preparation	① Notification and coordination of monitoring schedule for the owner of the target stove ② Verification of measurement site by preliminary inspection ③ Arrangement of vehicles and drivers to carry the equipment ④ Provision of necessary supplies of consumables. ⑤ Confirmation of equipment status
2.	The Previous Day of Measurement Day	① Selection of equipment used for stack gas measurement ② Maintenance for: e.g. absorption bottle, trap box ③ Conditioning and pre-weighing of dust filters ④ Preparation of field recording sheets ⑤ Equipment preparation for loading
3.	Measurement Day	See Section 6.1
4.	The Next Day of Measurement Day	① Post-weighing of filter with sampled dust for dust measurement ② Data reduction and report production

6.1 Example of Monitoring Schedule on Measurement Day

An overview of the monitoring is shown below in accordance with the work flow of measurement for one day.

Some of the steps from the installation to the ending of the monitoring differ depending on whether manual operation equipment or automated equipment is used, as shown in Table 6-2.

Table 6-2 Work Flow on Measurement Day

	No.	Work Flow	
		With Manual Operation Equipment	With Automated Equipment
Transportation	①	Loading of the equipment on the carrying vehicle.	
	②	Departure to the Ger to be measured.	
	③	Arrival at site.	
Verification of Monitoring Site	①	Greeting to the owner of the Ger. Verification of room layout and work space for equipment installation inside/outside the Ger.	
	②	Unloading and shifting of the equipment at the Ger (the monitor side and the chimney side).	
	③	Preparation of power supply. Cleaning of the work place for equipment installation.	
	④	Interviewing the owner (about general information of the stove, operating schedule on the measurement day, the coal type, etc.). Record the information as a field note.	
Installation & Warming-up of Equipment	①	Determination of the equipment setting position inside the room. Performing the piping and wiring task between the monitor side and the chimney side.	
		Equipment: Gas meters, inclined manometer, etc.	Equipment; Gas meters, automated isokinetic sampler, etc.
	②	Warming-up of the stack gas analyzers. Turn ON the electric heater if it is cold inside the room.	
	③	Confirmation of the operability of the suction pump and the PC in the working environment.	

	④	Weighing of the absorption bottles as pre-weighing. Record as a field note.	
	⑤	Open the hole for measurement on the chimney. Rake the accumulated ash and clean the inside of the pipe. Attach the supporting rod on the flange of the measurement hole. Arrange the piping and the wiring of sampling tubes, the temperature signal code and the power cable.	
	⑥	Measure the chimney inner radius, and record them as a field note.	
	⑦	Calculate and record the measurement position on the cross-sectional area according to the size data of the chimney.	
	⑧	Wind pieces of adhesive tape around the sampling tube or the Pitot tube to mark the sampling positions where the tips of the sampling inlet are to be set on a cross-sectional area in a chimney.	
		Pipes to be marked: Pitot tube and dust sampling tube	Pipe to be marked: Only the integrated dust sampling tube
	⑨	Start up the PC and open the designated calculation sheet (Excel). Input the facility information and the measured atmospheric pressure value.	
		Use the calculation sheet for manual sampling. Use the dedicated barometer to measure the atmospheric pressure.	Use the calculation sheet for automated sampling. The automated dust sampler indicates thereon the measured value of atmospheric pressure.
	⑩	Join the tubes from the chimney side with tubes from the monitor side. Put the drain trap box into both the dust sampling line and the gas measurement line. Take measures against the cold climate to avoid moisture freezing inside the tubes. Check the leakage of the tubes.	
	⑪	Insert the sampling probes for the gas measurement and the moisture sampling, and the temperature sensor. Using heat resistant tape, fill the gap between the hole and sampling pipes.	
	⑫	Determine the starting and the/ending timings for the dust or the moisture sampling based on the information gathered from owner. Record the coal feeding until the end of the dust measurement.	
	⑬	Calibrate the stack gas analyzers by introducing reference gases. Then, start measurement of gas measurement items in the 'measurement mode'.	
Basic Measurement	①	Measure and record the temperature of the flue gas.	No basic measurement is required when the automated dust sampler is used.
	②	Measure and record the flue gas speed.	
	③	Take the moisture samples. Weigh the samples and record the results.	
Dust Sampling	①	Input the results of the basic measurement into the designated spreadsheet. Measure new static/dynamic pressures and the temperature of flue gas, and input those data again. Calculate the isokinetic sampling speed of the dust and determine the nozzle inner diameter to sample the dust. Fit the sampling probe into the measurement hole after assembling the sample head.	Determine the nozzle inner diameter for the dust sampling according to the displayed data such as flue gas speed, etc. Assemble the moisture sampling apparatus and install it in the measurement hole.
	②	Take three dust samples according to the guideline 'Stack Gas Measurement Protocol.'	
		Read out the instantaneous value of the dynamic pressure and the temperature displayed on devices every one minute, and adjust the sampling speed frequently.	The dust sampling is controlled automatically. Moisture sampling must be performed at the same timing as dust sampling.
	③	Keep the dust sample filter in the dedicated glass holder, and finish the entire measurement.	
Withdrawal	①	Retrieve the record sheet, the samples and the memories. Demount and reassemble the integrated equipment at both the chimney and the monitor sides and re-load all in carrier vehicle.	
	②	Clean the place where the equipment was installed. Let the stove owner know that you have	

		finished work and are leaving.
Storage	①	Put the equipment back in its original position on the shelves in the office. Place the record sheets in a file. Check the condition and conduct maintenance work for the equipment if it is required.
	②	Keep the dust sample filters in the desiccator after drying them in a drying oven.

6.1.1 When Manual Operation Equipment Is Used

Figure 6-1 shows an example of the monitoring steps for the day of measurement. The item numbers in Fig. 6-1 correspond to those in Table 6-2.

Because the operation conditions and the stack inner diameter differ for each stove, the time necessary for conducting the basic measurement and the dust sampling may be longer than that in the table below. When the gas components are collected and analyzed using the moisture sampling, the basic measurement and the work back in the laboratory after the sampling shall additionally be conducted.

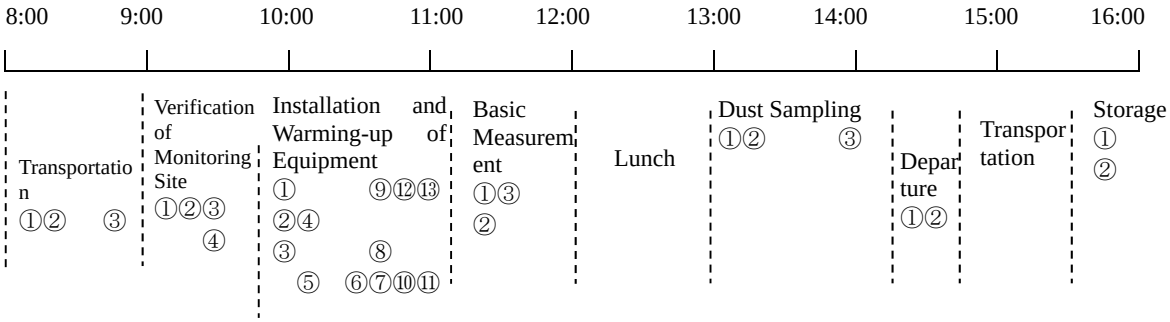


Fig. 6-1 Flow of Monitoring on Day of Measurement

6.1.2 When Automated Equipment Is Used

The monitoring steps are almost the same as those for using manual operation equipment apart from the absence of basic measurement, etc.

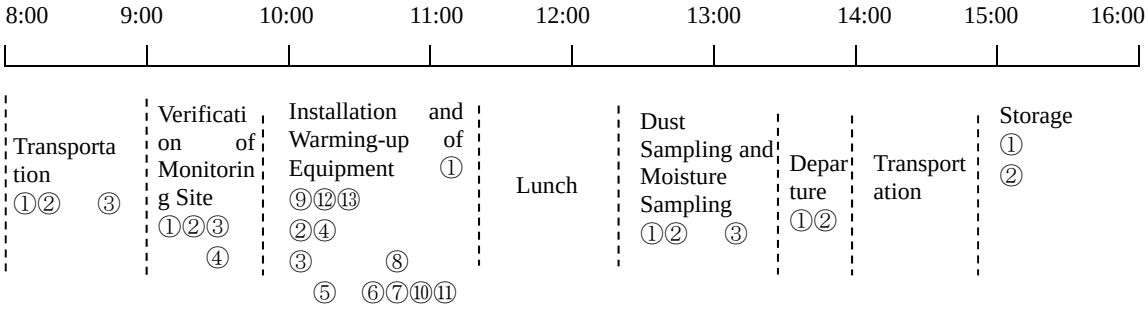


Fig. 6-2 Flow of Monitoring on Day of Measurement

7. Preparation before the Day of Monitoring

Before the day of the measurement, communication with external organizations, preparation and checks on the equipment to be used, etc., are conducted. This preparation is important for efficiently conducting the monitoring and avoiding mistakes on the measurement day.

7.1 Pre-Arrangement

7.1.1 Preparatory Notification to the Owner of the Stove to Be Monitored and, Coordination and Determination of the Day of Measurement

At least 10 days before the measurement day, call the home owner for which the measurement is planned and request permission for measurement. Obtain as much information as possible from the owner to check whether the stove is operating normally with no malfunctions and that the stove will be in operation as usual on the day of the measurement. Based on the outcome, the steps planned by both sides are checked to determine the day of the measurement.

7.1.2 Verification of Monitoring Site

When the day of the measurement has been determined on the phone, the state of the site should further be checked on the phone such as whether the space for the measurement work can be secured. For the house to be measured for the first time, a preliminary visit should be made before the actual measurement.

Some sites may impose the following difficulties on the measurement work:

Table 7-1 Points to Be Checked in Preliminary Visit to Site

Defect	Countermeasure
The duct has no measurement hole.	The cost for the new hole shall be borne by the measuring party.
The space in which to position the measuring equipment is small.	Get the permission of dislodge the household effects from Ger to secure the space for measurement. If it is not possible, should be excluded from the measurement target.
The power supply is unstable.	When the power supply cannot be stabilized, the Ger is excluded from the measurement target.
The power capacity of the power supply is insufficient.	The insufficient amount shall be complemented by obtaining other power from a neighboring house or using a power generator.
The chimney is clogged and the flue gas is not smoothly discharged.	The Ger shall be excluded from the measurement target. This Ger shall be measured after the chimney is replaced.
The measurement hole is installed at a high position and it is dangerous to use it.	The Ger shall be excluded from the measurement target.
The scaffold around the duct is dangerous.	

7.1.3 Arrangement of Vehicles and Drivers to Carry Equipment

Vehicles to be used on the day of measurement (for monitoring technicians and to carry the equipment) and drivers for them shall be secured in advance. Employment agreements with them shall be concluded also in advance when necessary.

7.1.4 Provision of Necessary Supplies of Consumables, etc.

In the monitoring, the consumables shown below (examples) are used. Therefore, sufficient consumables shall be supplied.

Dust filter, plastic tape, wire, silicone tube, silica gel, $CaCl_2$, cotton work gloves (which shall be reused after washing to the extent possible)

It shall be confirmed early that no device is faulty.

7.2 Preparation on Previous Day of Measurement

7.2.1 Selection of Equipment to Be Used

The features of the performance of the main devices are as shown in Chapter 4. Table 7.2 shows simplified options for each of the devices.

A combination of the automated stack gas analyzer and the automated isokinetic dust sampler is determined as the best combination taking into consideration the large number of data collected, the measurement precision, and the simplicity of measurement work.

Table 7-2 Features of Manual Operation and Automated Devices

Use of Device	Name of Device	Feature
Gas Speed Measurement	Inclined manometer (as a pressure gauge)	The operation is complicated and the accuracy is low.
	Automated isokinetic dust sampler	Operation and recording are automated and the accuracy is excellent.
Analysis of Gas Components	Wet type gas sampler (SO_2, NOx)	Only one piece of data can be obtained and it is difficult for this data to represent the status.
	Stack Gas Analyzer (TESTO)	Few data can be obtained and it is difficult for these pieces of data to represent the status.
	Automated Stack Gas Analyzer (PG-250) Automated Stack Gas Analyzer (HT-3000)	The data can continuously be obtained and the data has high capability as representative data.
Dust Sampling	Manual isokinetic dust sampler	The gas speed and the temperature vary significantly in a stove. The manual control of these items tends to be inaccurate. Therefore, the accuracy is intermediate.
	Automated isokinetic dust sampler	The control is automated and the accuracy is relatively high.

The situation of power supply is poor especially in local area such as Ger district in Ulaanbaatar City, the power outage or insufficient power capacity have been occurred very often. When all measurement devices are turned on at site, sometimes some of delicate devices could not keep working or work in abnormal condition that results to obtain the unreliable measurement data. Power generator is essential device to prepare for Ger stove measurement.

7.2.2 Maintenance of Equipment Used, and Pre-Process and Pre-Weighing of Dust Sampling Filter

The preparation of the dust-sampling filter shall be started in the morning of the previous day of sampling. The following operations shall be conducted on new cylindrical filters (Five or more

filters shall be prepared for one stove):

Table 7-3 Preparation Procedure for Dust Cylindrical Filter

No.	Preparation Procedure for Paper Filters
1	When the stack gas temperature is low, select glass-fiber cylindrical filters. When the stack gas temperature exceeds 200℃, select silica-fiber tube-type paper filters.
2	Provide each of the cylindrical filters with a serial number (see the filter weighing sheet). Handle the filters with clean hands to avoid dust contamination.
3	Place the cylindrical filters longitudinally in a beaker (with their openings upward) and put the beaker as it is in an oven.
4	Dry them in the oven at 110℃. Turn OFF the oven after one hour and leave the beaker to cool.
5	When the beaker is somewhat cooled, move the beaker with the paper filters in it using a pair of tongs into a dedicated desiccator.
6	Leave the beaker to be cooled in the desiccator as it is for two or more hours in its dry state until the temperature of the filters becomes room temperature.
7	Take one of the filters out of the desiccator and immediately weigh each filter using a 10^{-4}-g scale. Record the weight of the filter as a pre-sampling weight with the filter number.
8	Store the filter after weighing it. Place the filters in the cylindrical filter case (the dedicated glass bottle) or the case that has been storing the new paper filters.

Silica Filter


Dryer


Filters are dried.


The paper filters are cooled in the desiccator to room temperature.

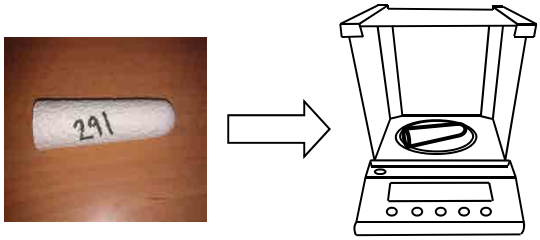


Fig. 7-1 Preparation of Dust Paper Filter

As the maintenance of other devices, for example, the following checks, cleaning, etc., shall be conducted:

Table 7-4 Important Points of Device Maintenance

Clean the dust-sampling nozzle. Check the presence of packing of the dust sampling tube.
Maintenance of absorption bottle (Sheffield bottle): When 1/3 of $CaCl_2$ is dissolved, replace the bottle. When the portion around the cock is clogged with silicone grease, clean the clogged portion. Remove the stain on the gas inlet. Conduct checks on leakages and clogging.
When the inclined manometer is used; Check whether the alcohol is present.
Oil Pump: Discharge only the contaminated oil. Check whether the position of the oil level is normal and, when the oil is insufficient, replenish with new oil.
Dry-Type Gas Meter: When no temperature is displayed, replace the battery.
Stack Gas Analyzer: Check whether a significant shift is observed for the response value when the reference gas is introduced.
Check whether any of the pipes is clogged with water or dust. When any leakage is found, cut off the leaking portion.
Check the inexpensive electric appliances (such as plugs and electric heaters) have no disconnected wires.

7.2.3 Preparation of Field Recording Sheet

Each field recording sheet (in Mongolian) is prepared. Make copies from the original sheet.

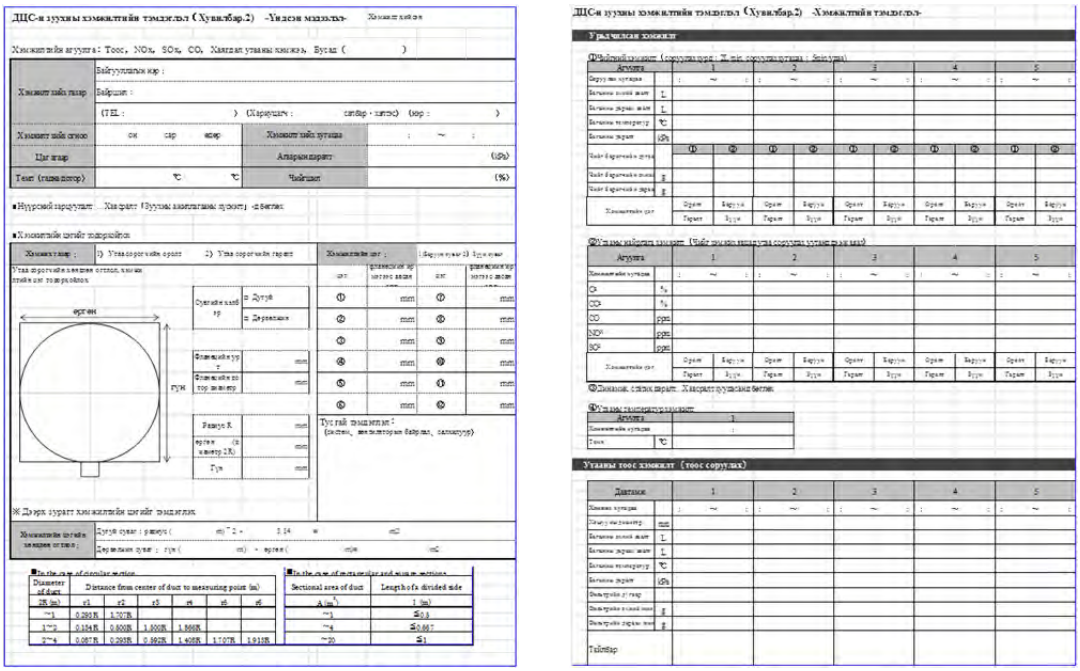


Fig. 7-2 Field Recording Sheet (Example)

7.2.4 Preparation for Carrying Equipment

If the devices were gathered in the morning of the day of the measurement, there would be insufficient time. All the devices to be used shall be prepared and gathered in the machinery room on the previous day. Use the device checklist to ensure that no necessary devices are left behind.

8. Work Steps to Be Performed before Measurement (Day of Measurement)

The procedure and remarks will be described for each work step according to the order of items in Table 6-2.

8.1 Move to Site

On the previous day, load all the devices collectively put in the machinery room, onto the device carrier vehicle. Move the devices quickly using a dolly to avoid breakages.

Fig. 8-1 Loading of Devices

Pay attention to the following items when loading the device on the vehicle:

Table 8-1 Points Requiring Attention in Loading Devices on the Vehicle

Carefully arrange the devices to be put in the cargo room on the vehicle to avoid damage caused by driving on bumpy roads.
Do not crush soft items by putting hard items on them or next to them.
Use cushions for fragile items and put the fragile items in baskets to the extent possible.
Always put precision instruments in their dedicated carry boxes.
Using ropes, fix items to avoid movement when the vehicle drives on bumpy roads. Otherwise, sandwich these items between heavy items.

When the vehicle is involved in heavy traffic after starting from base, contact the owner of the Ger to inform the manager of the delay and the estimated arrival time.

When the condition of the road surface is bad, drive the vehicle slowly to avoid breaking the devices loaded thereon due to bumps on the road.

8.2 Checks to Be Conducted on Site (Immediately after Arrival)

8.2.1 Greeting, Checks on Working Space, Carrying-in of Devices

After arrival, take time to greet the Ger owner and obtain permission to enter the premises. After obtaining permission, drive the vehicle into the premises.

The leader of the measurement team shall observe "the inside of the Ger and the vicinity of the stack" and shall check the spaces in which to install the devices (because the measuring devices are installed being divided into two for the two positions of the stack side position and the monitoring side position).

The positions shall be determined under consultation with the Ger owner taking into consideration the size, the location, the piping of each working space not to interfere with the life of family.

Fig. 8-2 Representative Example of Device Installation

The size of the room and the positions of the household effects differ depending on the house and, therefore, the arrangement of the devices is changed as follows according to the place.

It is necessary to put the stack gas analyzers, the oil pump, the PC, etc. in a warm room for them to operate. In the winter in Mongolia, air pollution becomes heavy and the temperature may fall to -30℃. When cold air enters the room, the temperature may fall to -10℃ or lower. In this operation environment, some devices may lack measurement precision even though they seem to operate. Therefore, care must be taken to select the places in which to install the devices.

Table 8-2 Points to Requiring Attention in Selecting the Installation Positions

The position must have electric outlets available for the measurement and must be within the range for the power cable to reach.
The positions must allow the piping and wiring to be installed to connect the chimney side and the monitor side.
The positions must be free from dripping water and secure from large trash falling on the measuring devices.
The room must be ventilated so that smoke from the stove does not accumulate in the room.
Enough work space surrounding the stove to be measured.
The scaffold around the chimney: needs a sufficient space that is not slippery, too high, or easy to fall from.

Ask the Ger owner where the electric outlets are (two or more outlets are preferable) and secure the power by connecting the power source drum to the outlets. After determining the installation positions, remove any trash and obstacles around the installation positions.

8.2.2 Interview for Facility Information, Operation Schedule, etc.

When the installation positions of the devices have been determined and the carrying of the devices has started, the leader of the measurement team shall interview the stove owner to obtain information on the facility operation. Simultaneously, the information shall be recorded on the record sheet (see the table on the right).

Based on this information, the measurement schedule shall be determined for the day of the measurement (the starting time of the measurement and the length of sampling time).

The information obtained in the interview will be useful when the validity of the calculated report value is verified in the data reduction conducted on a later day.

① Operation Policy for Day of Measurement

The timings to feed coal, to remove the ash, and at what intervals.

Is the combustion of the coal close to that in winter or is it suppressed in comparison?

② Demand Origin of Hot Water

.

③ Stove

The model, the coal feeding method, the discharged gas treatment scheme (dust removal and desulfurization), and checks on faulty parts

④ Coal

Place of production, type, size, and the average weight of coal to feed.

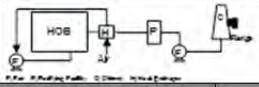
No.		1	
HOB Model		0000	
Photograph		 HOB  Stack	
System (for one stack)			
Item for Record		Content (Example)	Remarks
Basic Item	Place of Installation	0000	
	Date of Visit	Jan. 29, 2012	
	Temperature of Day of Visit	Average: -23 degrees (Max.: -13 and Min.: -31)	
Specification of Boiler	Capacity (MW)		
	Date of Installation		
	Quantity	One	
	Fan Type	Equivalent	
	Coal Feeding Type	Manual	
	Measurement Hole Position	Stack	
	Dust Sampler Type	Cyclone	
	Desulfurizer Type	None	
State of Operation	Supplied Water Set Temperature (℃)	80	
	Fan Operation Scheme	Intermittent Operation	
	Timings to Turn ON and OFF Fan	Fan is turned OFF when the returning water is 80℃ or hotter, and is turned ON when the returning water is around 70℃.	
	Leakage into Stack, etc.	A slight blowout before the stack	
	Use of Damper	Not verifiable	A damper is used.
	How to Put out Clinker	Pushing out into a clinker receiver behind the HOB	
	Frequency of Clinker Removal	Before every coal feeding	
	Frequency of Raking Coal	Several times an hour	
	Maintenance of Dust Collector	Cleaning once in a half day	
Items for Fuel	Type of Coal	Raibilb	
	Size of Coal	Powder coal	About several centimeters
	Container to Feed Coal	Shovel	
	Coal Feeding Time Interval	Once in 20 minutes for about 10 shovelfuls	
	Feeding Amount at Time of Visit (kg/h)	220	
	Midwinter Feeding Amount (kg/h)	270	
	Other Items to Burn	Sometimes, paper trash	
Demand for Hot Water	Demand Origin	Schools, hospitals, and houses around the boiler	
	Demand Time Zone	All day long (no supply discontinuation)	
Other Items Observed or Interviewed		- The coal is fed such that the thickness of the coal on the fire grate is 8 to 12 cm. - The backup HOB is operated only in the cold season. - The coal is supplied to plural HOBs each at a different timing from each other. - Coal feeding is regulated based on the observation of the quality of the ash.	

Fig. 8-3 Example of Boiler Information Record

8.3 Installation and Warming up of Equipment

The place for installing each device differs depending on: the composition of the devices and the layout of the room; and which devices are used.

The measurement hole and devices were located inside Ger in most of measured case. The sampling pipes are not cooled by outside cold air, a lot of water vapor existing in the flue gas will change into water inside the pipe without frozen, and come to the monitor side as is. Therefore, it is required to capture the water liquid at the trap bottle before reaching to the dust sampling system or gas analyzers.

8.3.1 Safety Measures

8.3.1.1 Items to Wear

Refer to the HOB guideline, Helmet and safety sues do not required to wear due to indoor work.

8.3.1.2 Points Requiring Attention when Working in High-Places

Measurement is generally carried out at Ger or ordinary home, there is no work at high place unlike a large-scale boiler such as Thermal Power Plants. If the sampling is conducted around the chimney outside which extruded from the house roof, Install the chimney-side devices using ropes and take the safety provisions into consideration. Lift the devices with two persons as a team synchronizing the timing between the two by using a sign.

<Stack Side> Check the scaffold carefully. Tie the end of the rope to a rail of a fence, etc. Wind the unused portion of the rope tightly not to obstruct the work and to avoid fouling of the rope on the legs of the technicians.

When an article is lifted up, lift the article slowly directly upward to avoid the article swinging.

<Monitor Side> Wind the rope once around the device to be lifted (if the rope is tied at only the handgrip of the device, the lid of the device may open and the articles retained therein may fall out). When the lifting has been started, the persons standing under the device must move away to avoid standing beneath the device.

When a pipe lifted up is fixed, take into consideration the position to fix the plastic pipe to avoid being squashed by its own weight.

Correctly Fixed

Incorrectly Fixed: The pipe gets squashed by its own weight where it is fixed.

Fig. 8-4 How to Fix the Pipe

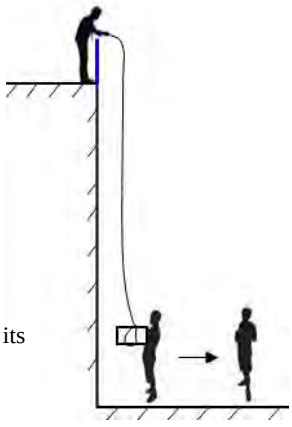


Fig. 8-5 Lifting up of Device

8.3.2 Configuration and Connection for Manual Operation Devices

1） Temperature Measuring Device

A thermocouple of the K type shall be used as the temperature sensor. There are two types of apparatus for displaying the temperature data (the portable temperature display or the logger). The logger not only displays the temperature but also records and stores the temperature every second.

Fig. 8-6 Temperature Measuring Devices

The logger is often used because it can automatically record. The logger can accept other input signals (such as a measurement output of the stack gas analyzer) and, therefore, the logger shall be installed on the monitor side. When the distance is long between the stack side and the monitor side, the sides shall be connected using a long "dedicated temperature compensating conductor" (an ordinary signal line must not be used).

2） Gas Speed Measuring Device

The Pitot tube and a pressure gauge are used to measure the stack gas speed. A pressure gauge as a manual operation device is an inclined manometer.

Fig. 8-7 Gas Speed Measuring Device

The inclined manometer includes a liquid sealed therein and is used together with the liquid. In winter in Mongolia, the liquid must not freeze and, therefore, the liquid shall be ethyl-alcohol, which has a low freezing point (where available).

The Pitot tube and the inclined manometer are connected using two tubes and, when the distance is long between the stack side and the monitor side, the section in between may be connected by silicone hoses or Teflon tubes.

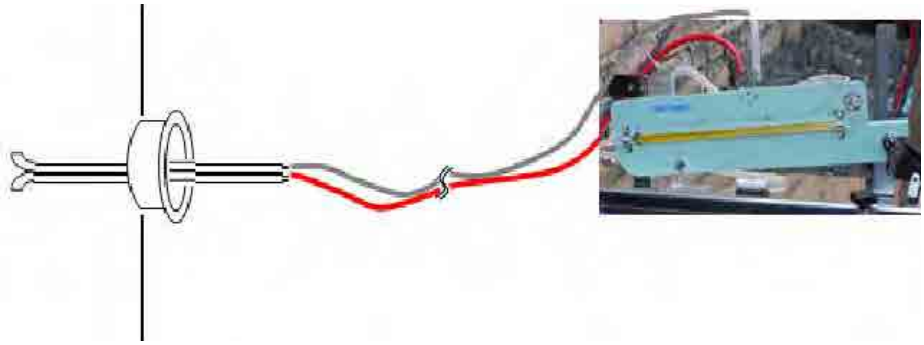


Fig. 8-8 Image of Installation of Gas Speed Measuring Devices

3） Moisture Sampling Devices

The stack-side devices consist of "the sampling tube, the Sheffield bottle, and a ribbon heater."

The monitor-side devices consist of "the trap, the suction pump (with a flow regulating cock), and the gas meter." The devices made in Japan include those that are driven at AC100V and it is necessary to use transformers to reduce the voltage from 220 V to 100 V.

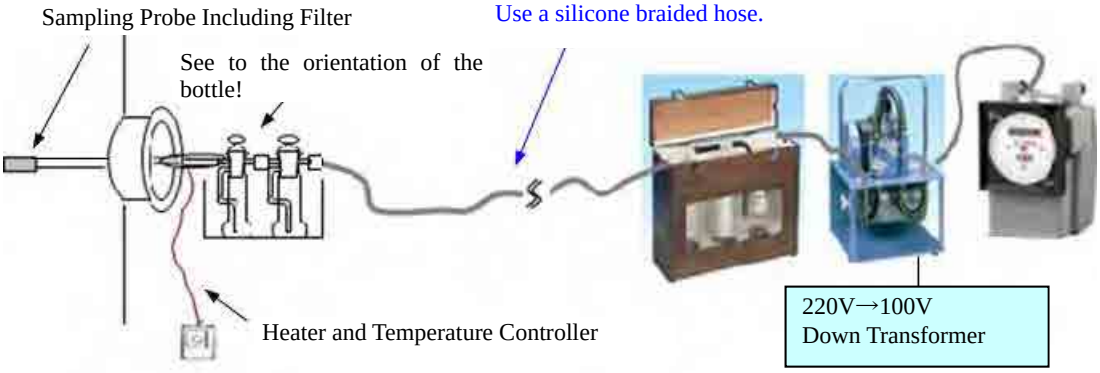
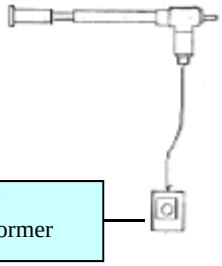


Fig. 8-9 Image of Installation of Moisture Sampling Devices

The Sheffield bottle is a tool for capturing only the steam in the stack gas. The sampling probe must be attached with a filter to avoid entry of dust in the stack gas into the Sheffield bottle. Because the ambient air is cold, the piping extending to the Sheffield bottle needs to be heated by a heater as shown in Fig. 8-7 (without the heating, the steam changes into water droplets, which do not enter the Sheffield bottle).



When the steam is adsorbed, the steam generates heat and the Sheffield bottle becomes hot. Therefore, the lower half of the bottle is usually sunk in the water tank (however, in winter, the atmosphere cools the bottle and the water tank is unnecessary).

A heating sampling probe as shown in the figure on the right may be used instead of "the sampling probe plus the ribbon heater."

4） Gas Component Measuring Devices (SO_2, NOx, CO, CO_2, and O_2）

The manual operation devices for measuring the gas components in the stack gas are roughly classified into the following two types:

① Wet Type Gas Sampling Set

See the Moisture Analysis Technical Manual. This book does not introduce this set because the measurement can be conducted only several times and the data is too poor to be used as representative data.

② Stack Gas Analyzer (Chemical Sensor Type)

The HOB often discharges CO gas whose concentration exceeds 1,000 ppm. Therefore, the sensitivity of the chemical-sensor stack gas analyzer is degraded due to the degradation of the sensor. For this reason, measurement of a high-concentration CO gas for a long time must be avoided. The measurement must be finished in a short time and it is necessary after obtaining one measured value to purge the line in the analyzer with the air in the room for a while.

To avoid the degradation of the sensor to the extent possible, the following measures shall be employed for the sampling (with this measuring method, the stack side and the monitor side are never connected to each other):

- Sample the stack gas in the gas bag using the twin balls. Sample the stack gas slowly taking five minutes for one bag (suction regularly to fill the bag such that the concentration of the sample in one bag after the sampling averages the gas concentration which fluctuates in five minutes).
- Analyze the concentration of the sample in the gas bag in a short time using the chemical-sensor stack gas analyzer and obtain one piece of data as a five-minute average value.

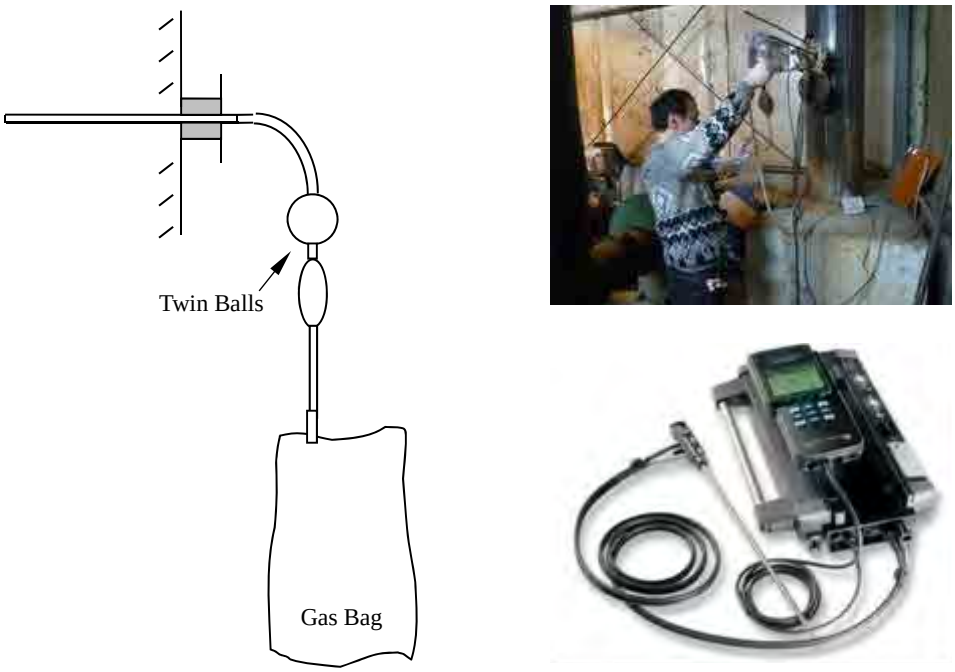


Fig. 8-10 Image of Installation of Gas Component Measuring Devices

The stack gas analyzer needs to be placed in a warm room (because its operation temperature is 0

to 40℃). The measurement in this method only gives several pieces of data for one stove and the data is poor as representative data similarly to that given by the Wet analysis method.

5） Dust Sampling Device

The stack side consists of "the dust sampling probe." The dust nozzle and the tube-type paper filter are set in the sampling probe.

The monitor side consists of "the trap, the suction pump (with the flow regulating valve), and the gas meter." The devices made in Japan include those that are driven at AC100V and it is necessary to use transformers to reduce the voltage from 220 V to 100 V.

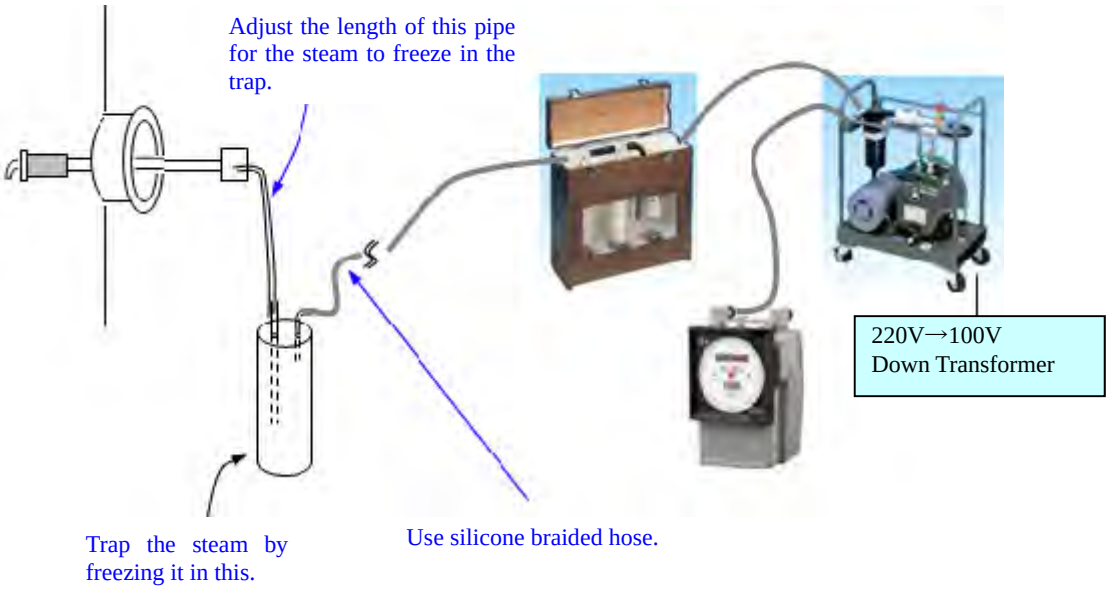


Fig. 8-11 Image of Installation of Dust Sampling Devices

8.3.3 Configuration and Connection for Automated Devices

As the configuration of the devices, the following items are different between the automated devices and the manual operation devices:

Table 8-3 Difference between Automated Devices and Manual Operation Devices

Name of Device	Difference between Automated Device and Manual Operation Device
Moisture Measuring Device	No difference. The same device is used for the manual measurement and the automated measurement.
Gas Component Measuring Device	Automated stack gas analyzer is used as the automated device.
Temperature Measuring Device	As the automated device, the automated dust sampler automatically measures both the temperature and the gas speed.
Gas Speed Measuring Device	
Dust Sampling Device	

An image of the installation of the automated devices is shown below.

1） Moisture Sampling Device

Same as that of the manual operation device.

2） Gas Component Measuring Device (SO_2, NOx, CO, CO_2, and O_2)

The stack gas analyzer (optical sensor type), which is robust against the influence of the

interfering gases and can continuously measure, collects data of the concentration at a rate of a piece of data in 10 seconds (in the current setting).

The dust and the moisture in the stack gas must not enter the stack gas analyzer. As shown in the figure below, the parts for removing the dust and the moisture are inserted at various positions of the stack gas introducing line.

As to the Ger stove, the CO concentration sometimes becomes high that is in order of %. To precisely measure the concentration from a low concentration to a high concentration, prepare a stack gas analyzer for a low concentration and that for a high concentration and operate them in parallel to each other. According to the flow, suction the stack gas using a small pump and, thereafter, distribute the gas to input the gas into each of the measuring devices.

The devices made in Japan include those that are driven at AC100V and it is necessary to use transformers to reduce the voltage from 220 V to 100 V. It takes one hour to warm up the automated stack gas analyzer and, thereafter, it takes a further 30 minutes because the calibration must be conducted using the reference gas. To quickly conduct the measurement work, it is important to pre-warm the automated stack gas analyzers by installing these devices earlier than the other devices such as the dust samplers.

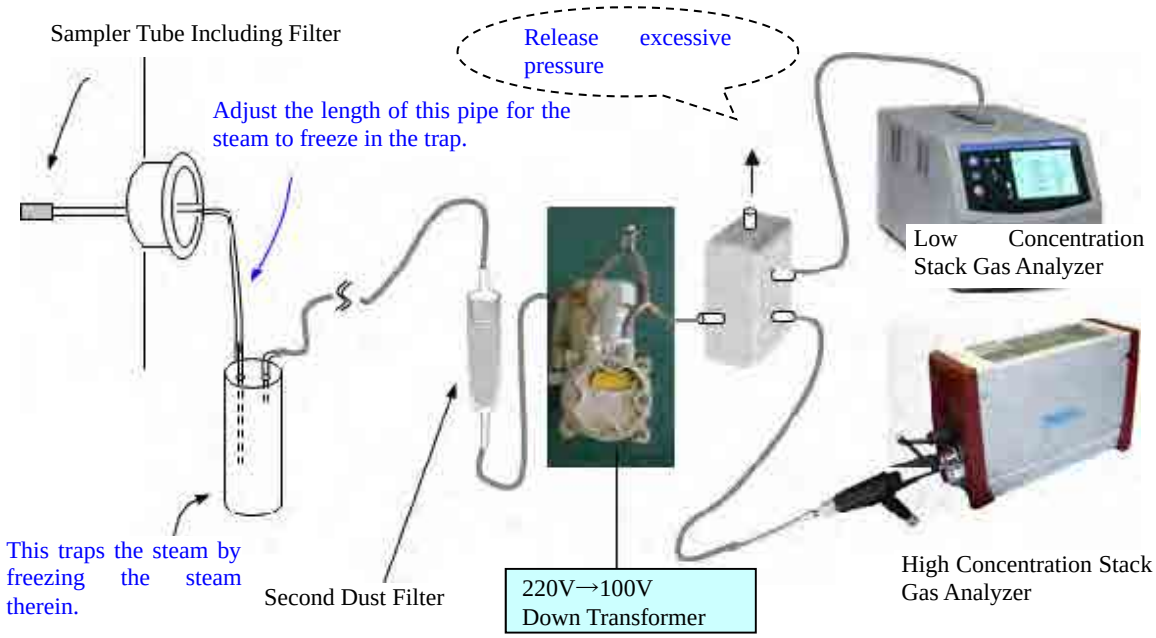


Fig. 8-12 Image of Installation of Automated Gas Component Measuring Devices

The data is automatically recorded into the logger by the low concentration stack gas analyzer and into an incorporated SD card by the device for the high concentration.

An uninterruptible power source shall be prepared for a power failure. This source can maintain the operation for several tens of minutes during a power failure.

3） Dust Sampling Devices

The stack side consists of "the dust sampling probe." The dust nozzle and a cylindrical filter are set in the sampling probe.

The monitor side consists of "the trap, the suction pump (with a flow regulating valve), the gas meter, and the sampling controller." The devices made in Japan include those that are driven at AC100V and it is necessary to use transformers to reduce the voltage from 220 V to 100 V.

Gas meters include wet-type gas meters and dry gas meters. When a wet-type gas meter is used, put antifreeze liquid in it.

See the technical manual for the piping and connection to the automated dust sampler.

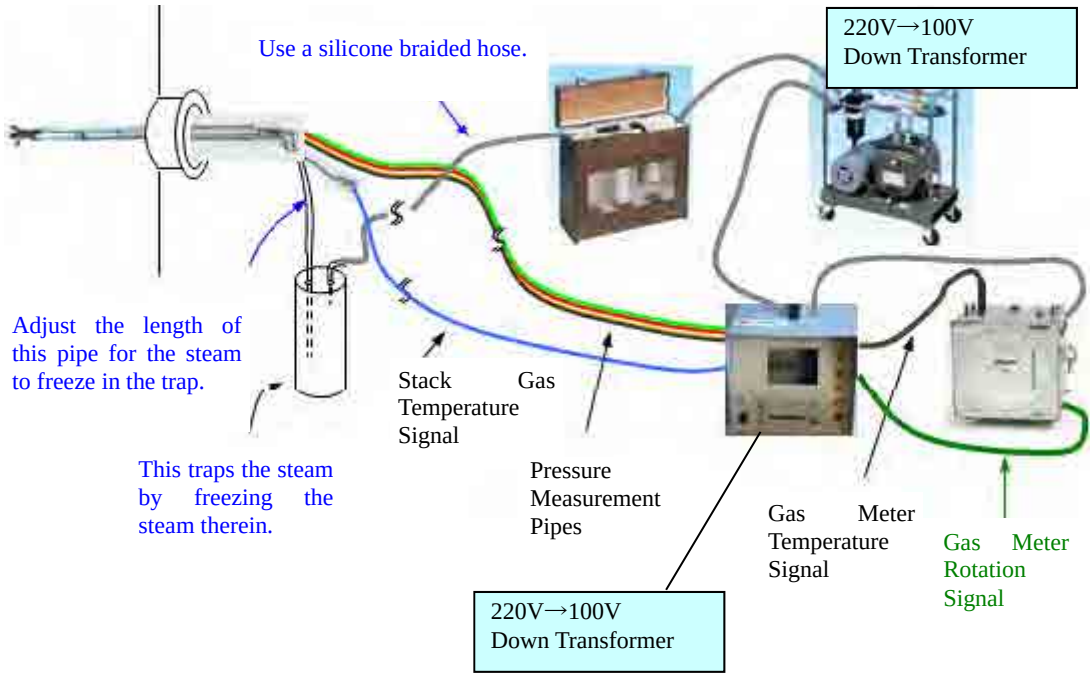


Fig. 8-13 Image of Installation of Automated Dust Sampling Devices

8.4 Checks after Installation

8.4.1 Checks on Operation

The following checks shall be conducted to check whether the main devices operate normally:

Table 8-4 Items to Be Checked after Warming up

Name of Device	Item to Be Checked
Suction Pump	Start up the oil pump immediately while the pump is warm after it is installed. When the room is cold, heat the oil tank. Once the pump is turned on, keep the pump rotating (because, when the room is cold, it is difficult to turn ON the pump again once the pump is turned OFF).
Gas Meter	When the pump is connected to the gas meter and is turned on, check that the gauge of the gas meter rotates round and round.
PC	The PC does not work well when the room is cold. Warm the PC properly using an electric blanket.
Stack Gas Analyzer	Turn ON this analyzer immediately after its installation (because it takes one hour to warm up the analyzer). Put the analyzer in the state for suctioning the room atmosphere. Connect the analyzer to the logger. (Conduct the operations following the technical manual.) If the stack gas analyzer is placed in the vehicle, the stack gas suctioned by the analyzer fills the inside of the vehicle and harms the health of the members. The stack gas may be discharged out of the vehicle by connecting a pipe to the outlet of the analyzer. However, when the pipe is thin and long, it influences the measured value and, therefore, the pipe must be thick and short.
Logger	Set the USB memory and check that the following input signals are sent: ・The measured values of the five items of PG-250 (SO_2, NOx, CO, CO_2, and O_2) ・The measured value of the stack gas temperature sensor (Conduct the operations following the technical manual.)
Inclined Manometer (Manual Operation Device)	Set the inclination to be 1/20. With the differential pressure that is zero, check that the liquid level of the included liquid (ethyl alcohol) is zero to 5 cm on the scale. If the liquid is insufficient, replenish the tank with liquid. When this zero position is checked, take care to avoid any wind entering from the two inlets.
Automated Dust Sampler	After turning this sampler ON, check the display on the screen. Check that there is sufficient printer paper. Conduct zero adjustment with the differential pressure that is zero.
All Devices	When all the devices are used, the power used may exceed the power source capacity and the breakers may drop depending on the place. Complement the electric power by obtaining another power source from a neighboring house or using a power generator.

8.4.2 Leak Check on Pipes

As described in Item 8.3, the devices are connected to each other using many joint pipes. If a joint pipe is decoupled or has a hole, normal measurement cannot be conducted because the room atmosphere enters through the decoupled portion or the hole.

After connecting the pipes, the pipes must be checked to confirm that no leakage exists, according to the following method:

8.4.2.1 Moisture Line and Dust Line

Conduct the leak check according to the following procedure:

1) Operate the pump (an arbitrary speed may be employed).

2) Check that the gauge of the gas meter rotates (adjust the rotation speed to a proper speed using the flow regulating valve of the pump).

3) Pull out the end of the pipe on the stack side from the sampling probe and close the tip of the tube using a finger.

4) Observe the gauge of the gas meter. When no leak exists in the pipe, the rotation gradually slows and finally stops.

5) If the rotation does not stop, take off the pipe joint starting with the pipe joint closer to the pump and repeat the checks in ③④. Find the position of the leakage and repair the leakage.

The suction flow of the dust sampling pump is large and the rotation of the gauge usually stops shortly after the pump starts suctioning. In contrast, the flow of the moisture pump is relatively small and, therefore, it takes time to remove the air from the pipe. Therefore, be prepared to wait longer than estimated. Somewhat increasing the flow using the regulating valve results in a shorter time to suction the air.

However, when the trap bottle is a plastic bottle, the bottle is gradually crushed as the inside of the pipe becomes a vacuum. It is better to check the leak without the trap bottle not to break the trap bottle. To check the leakage of only the trap bottle, suck on the bottle.

It is necessary to take care when the leak check is conducted on the automated dust sampling devices. This leak check is described in 10.22.

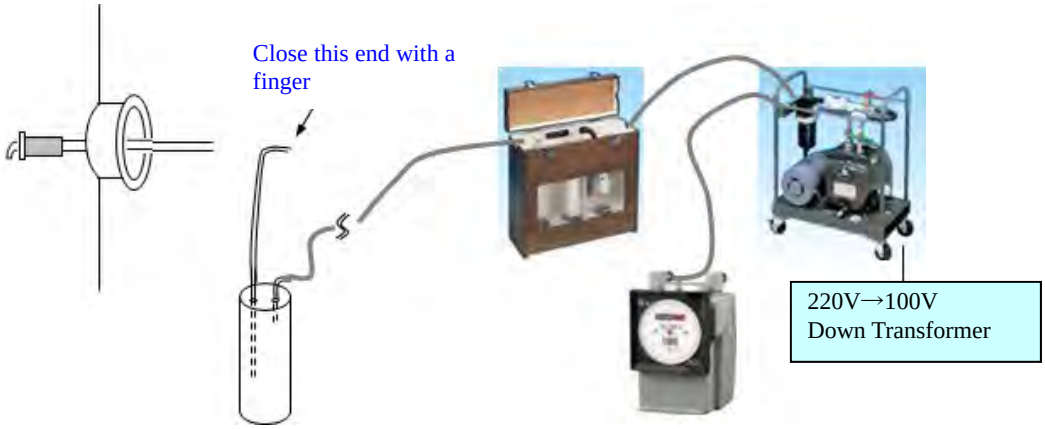


Fig. 8-14 Leak Check on Pipes

8.4.2.2 Line for Gas Components

Install the gas meter downstream of the suction pump and conduct checks according to the same method as that described in 8.4.1.

8.4.3 Measurement of Duct Diameter and Flange Length, and Calculation of Measurement Points

For the gas speed measurement and the dust sampling, calculation must be conducted to determine at which point the stack gas and the dust are collected in the cross section of the duct for each facility. The figure of the image below shows the case where the cross sectional shape of the duct is a circle.

As the gas speed differs depending on the position in the duct, in order to obtain a representative value as one duct, plural measurement points are usually provided in the cross section of the duct.

For the measurement at Ger stove, the sampling position is only one point, center of the cross section, since generally the diameter of chimney does not exceed 56 cm. See the technical manual for the method of calculating the positions of the sampling points (the black points in Fig. 8-15 below).

When the dust sampling probe and the Pitot tubes are inserted into the duct, adjust the length of the insertion of the probes such that the ends of these probes are placed at these positions.

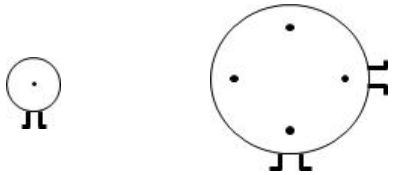


Fig. 8-15 Positions of Measurement Points in Cross Section of Duct (for Circular Duct)

The dust sampling probe, Gas collecting tube and Temperature sensor are to be installed into chimney. Open two holes, around 10 cm diameter, to insert the probes above in accordance with the small size chimney.

Measure the size of the inner diameter of the duct using a relatively long pipe. Based on these measured values, calculate the positions of the measurement points by manual calculation according to the technical manual and record the results in the recording paper sheet.

8.4.4 Start-up of PC, Preparation of Calculation Sheet, etc.

Start up the notebook PC and open the Excel calculation sheet dedicated to the stack gas measurement. Input all of the information obtained in the interview with the owner, the measurement results of the duct size, etc. Measure the atmospheric pressure and input the result into the calculation sheet.

8.4.5 Determination of How to Burn Fuels

Unlike HOBs or Thermal Power Plants, the user can make or put off fire anytime he needs for Ger stove operation. It is required for measurement leader to choose the start burning condition for measurement, whether start at no fire in stove (Cold start) or the warm condition with embers left inside (Hot start). Consideration is need on fuel condition before feeding for Cold start test, because it difficult to make fire if the fuel got wet or too cold. For Hot start, burning fuel and ashes left inside the stove have to be discharged as much as possible before starting, so that they won't influence to the accuracy of measured data. Burning operation of stove is not the same for use it at cooking or house heating. For cooking, burn the fuels in short time to provide the strong power. On the contrary, burn the fuels slowly for house heating so that let the pile of coal start burning from one side and finally fire reaches to the other side in long time. It is important to watch the burning condition and measurement control during the taking sample or measurement, since the flue gas condition and pollutants concentration vary by burning condition.

9. On-site Measurement Work 1 (For Manual Operation Equipment)

As shown in 6.1.1, preliminary measurement is required for stack gas measurement with manual operation equipment before dust sampling. A lot of data obtained through this preliminary measurement will be used for calculations to determine the control conditions of the manual type dust sampler for smooth dust sampling after the preliminary measurement.

9.1 Preliminary Measurement

After installing necessary equipment on the stack side and the monitor side after confirming they operate normally, start measurement of the temperature, flow speed and moisture step by step.

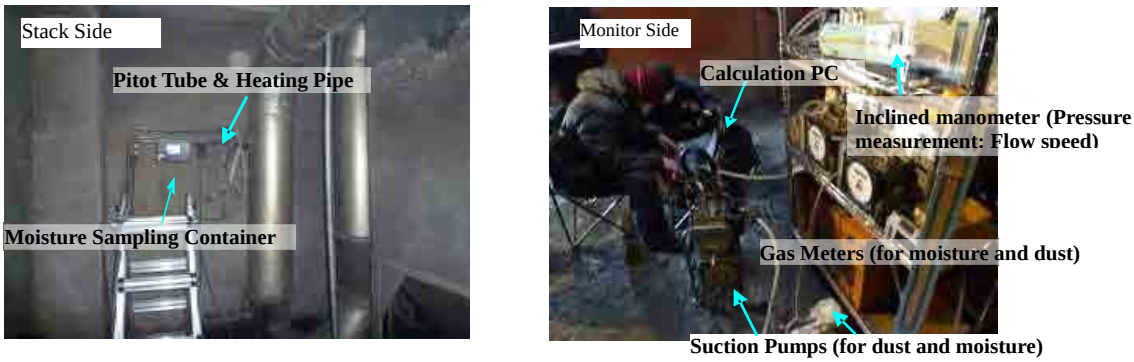


Figure 9-1 Measurement at the HOB Site

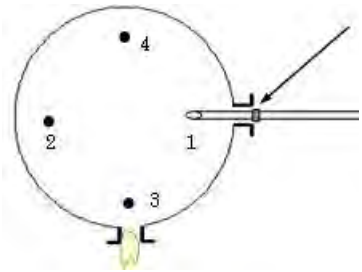
9.1.1 Measurement of the Temperature (Common to Manual and Automatic Equipment)

Measure the flue gas temperature in the duct with the equipment specified in 8.3.1.1. After observing the condition around one minute, read an approximate average value and write it down on the record sheet. The head of the Type K thermocouple may be located in any place inside the duct. However, take care for the tip not to be contact with the internal wall of the duct.

9.1.2 Measurement of the Flow speed (Manual)

The theory of flow speed measurement is specified in the technical manual.

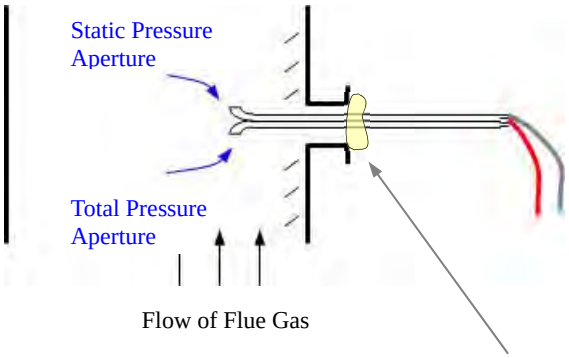
The following is a conceptual illustration for measurement of the flow rate at the four points in total in the duct. The tip of the Pitot tube is placed at the first point to measure the flow speed.



Insert the Pitot tube properly so that its tip may be located exactly at the first measuring point.
For this purpose, provide a tape marker at this position of the Pitot tube so that one can discern it when viewed from outside.
This position as a place of enrolling a adhesive tape should be determined beforehand, as calculated at 8.4.3.
The second point and subsequent points also are marked with adhesive tape as position reference.

Figure 9-2 Positions of the Pitot Tube for Measurement of the Flow Rate

At the tip of the Pitot tube, there are two apertures: the one facing to the flow of flue gas is called the total pressure aperture, while the other is called the static pressure aperture. The total pressure aperture must be directed squarely to the flow of flue gas (the angular tolerance is ±5°).



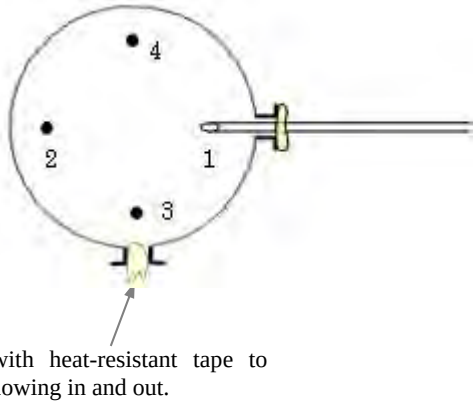


Figure 9-3 Measurement of the Flow Rate (Side View)

Figure 9-4 Measurement of the Flow Rate (Sectional View)

Measure the flow speed, following the procedure below. Write down the angle of the manometer (such as 1/20) and the pressure value measured at each point (marked on the scale of the inclined manometer) on the record sheet.

(1) Read the zero point of the inclined manometer.

Before inserting the Pitot tube into the duct, put the tip of the Pitot tube into a bag (to prevent it from being affected by a wind), and check the reading under the condition that the same atmospheric pressure is applied to the two apertures. That is, read the scale without differential pressure.

(2) Read the dynamic pressure value (Pa) and the static pressure value (kPa) at the first measuring point.

In the Figures 9-3 and 9-5, a red tube is used for connection to the total pressure side, while a grey tube is used for the static pressure side. Insert the Pitot tube slowly into the duct, and set it in the measuring position.

Figure 9-5 Inclined manometer

At this time, the level of ethyl alcohol becomes turbulent due to a shock caused by a large difference

between the pressure in duct and the atmospheric pressure, if any. When the difference is too large, the ethyl alcohol flies out to the glass bulb, overflowing the right edge of the scale. In this case, when introducing the Pitot tube, as a preparatory step, the red and grey tubes are pinched by hand not to produce a sharp shock. Keeping this state, set the Pitot tube just at the first reference point. Then, gradually open the plied tubes so that pressure may work on gently the inclined manometer. Not agitating the level of liquid is the cue to get a correct reading.

The value read here is equivalent to a dynamic pressure.

Then, detach the red tube (the total pressure side shown in the Figure 9-5) from the inclined manometer, and read the scale. The read value is equivalent to a static pressure. Depending on the stove, the static pressure in duct may become positive or negative. The magnitude of pressure also differs according to the stove.

When measuring a large positive or negative static pressure, set the angle of the inclined manometer at 1/10, 1/5, 1/3 or vertically. When the pressure is too large to measure with these inclinations, measure the value with the U-tube filled with water.

In this inclined manometer, the graduation of 10 is equivalent to 1,000Pa at the inclination of 1/10. Since the reading method used for this system is different from those in conventional products in which readings are given in millimeters, be careful not to make mistakes.

(3) Read dynamic and static pressure values at the other measuring points in the same manner as in (2).

Figure 9-6 Measurement of Flow speed

9.1.3 Measurement of Moisture Contents (Common to Manual and Automatic Equipment)

It is possible to determine the moisture concentration of the flue gas referring to the fact that the desiccant of CaCl2 included in a Shefield bottle increases its weight when absorbing the water. For details, refer to the technical manual. The measurement procedure is as follows.

(1) Take six Shefield bottles prepared for this purpose out of the storage box.

(2) Prepare an electric balance in conditioning. Place it on a flat surface inside the warm room and set it in correct regulation of level. Set the balance not to be affected by the wind.

(3) Make a zero setting for the electric balance.

(4) Weighing of Shefield bottles before use

Close the cock, and weigh each bottle. Before the measurement, completely remove any dirt and/or water adhering to the surface of the bottle with clean tissue paper.

Write down the original pre-measurement weight on the record sheet (together with the bottle number).

Figure 9-7 Weighing of the Shefield Bottles Before Use

(5) Then, connect two Shefield bottles with a silicon tube in order to store them as a set (three sets in total). When the connecting silicon tube is too long, there is a adverse possibility that the water may accumulate at the joint. When the connection tube is too short, it is easily detached. Connect the two bottles by using a tube of a proper length to reduce the connecting distance as much as possible.

(6) Installation of the Shefield Bottles

The figure below is the same as the Figure 8-9.

Set a set of Shefield bottles with their cocks closed at the measurement aperture paying attention to the direction of the bottles. Seal the clearance with heat-resistant tape.

Set a ribbon heater as closely as possible to the inlet of the bottle as shown in the figure, in order not to allow the vapor to turn to water under the effect of cold atmospheric air, before entering the bottle. Do not raise the temperature of the ribbon heater too much (the silicon tube may be burnt at an excessively high temperature).

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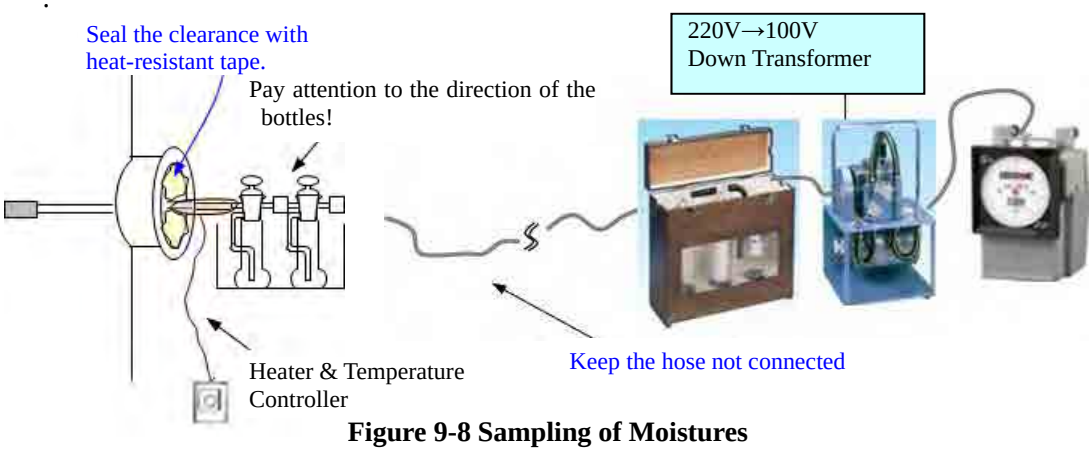


Figure 9-8 Sampling of Moistures

(7) Immediately before Starting Sampling

Before starting sampling, adjust the flow rate of the pump to approximately 1L/min. After stopping the pump, read the accumulated flow rate of the gas meter, and write it down on the record sheet as the read value before sampling. Confirm the bottle numbers of the set Shefield bottles.

(8) Timing of the Sampling

For collection of three sets of moisture samples in total, decide start time and stop time appropriately, depending on the operating status of the stove.

Usually, it takes five minutes for one set at a flow rate of approximately 1L/min, but the concentration of the flue gas from stove largely changes, depending on the operating condition of the stove. To obtain a representative average, the length of time, timing and suction speed for

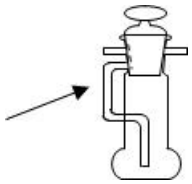
sampling may be changed. Refer to the "Stack Gas Measurement Protocol."

(9) Start of the Sampling

Before starting the sampling, attach the detached hose. Open the two cocks of the Shefield bottles by turning them to the open side (be careful to turn them to the right direction). Soon after the communication between the stack side and the monitor side, turn on the pump and start sampling. Use a walky-talky for smooth communication between the two sides, when needed.

When the sampling is started, water vapor goes into the bent tube of the Shefield bottle, making the inside of the tube fogged. Be sure to confirm this phenomenon.

This part becomes fogged when the sampling is started.



Measure the rotation time of the gas meter, and confirm that the suction rate is around 1L/min (the rate may be lower than this for a longer suction time).

(10) During the Sampling

Confirm that the sampling is going on smoothly with water drops adhering to the inside of the Shefield bottle. In addition, check that water vapor does not become water before going into the bottle due to the misalignment of the ribbon heater wrapped around the tube. If the heater is misaligned, wrap it properly. Read the temperature of the gas meter, and write it down on the record sheet. Check the rotational speed of the gas meter from time to time in order to confirm that the rate does not decline (if it has declined, clogging or leakage may be caused).

(11) End of the Sampling

Stop the pump when the scheduled closing time comes. Close the cocks of the Shefield bottles, and remove the first set of bottles for recovery. Take the reading of the gas meter, and write it down on the record sheet as the post-sampling value.

(12) Post-weighing of the Shefield Bottles

Completely remove any dust and/or moisture on the surface of the first set of recovered bottles with tissue paper. Then, weigh it with the electric balance, and write down its weight on the record sheet.

(13) Moisture Sampling for the Second and Third Sets

After finishing the sampling with the first set at (11), repeat the above steps from (6) through (12) to collect data with the second and third sets. Calculate the moisture concentration by using a dedicated dust calculation software. When the reading taken is found abnormal, an additional measurement is required with the fourth set.

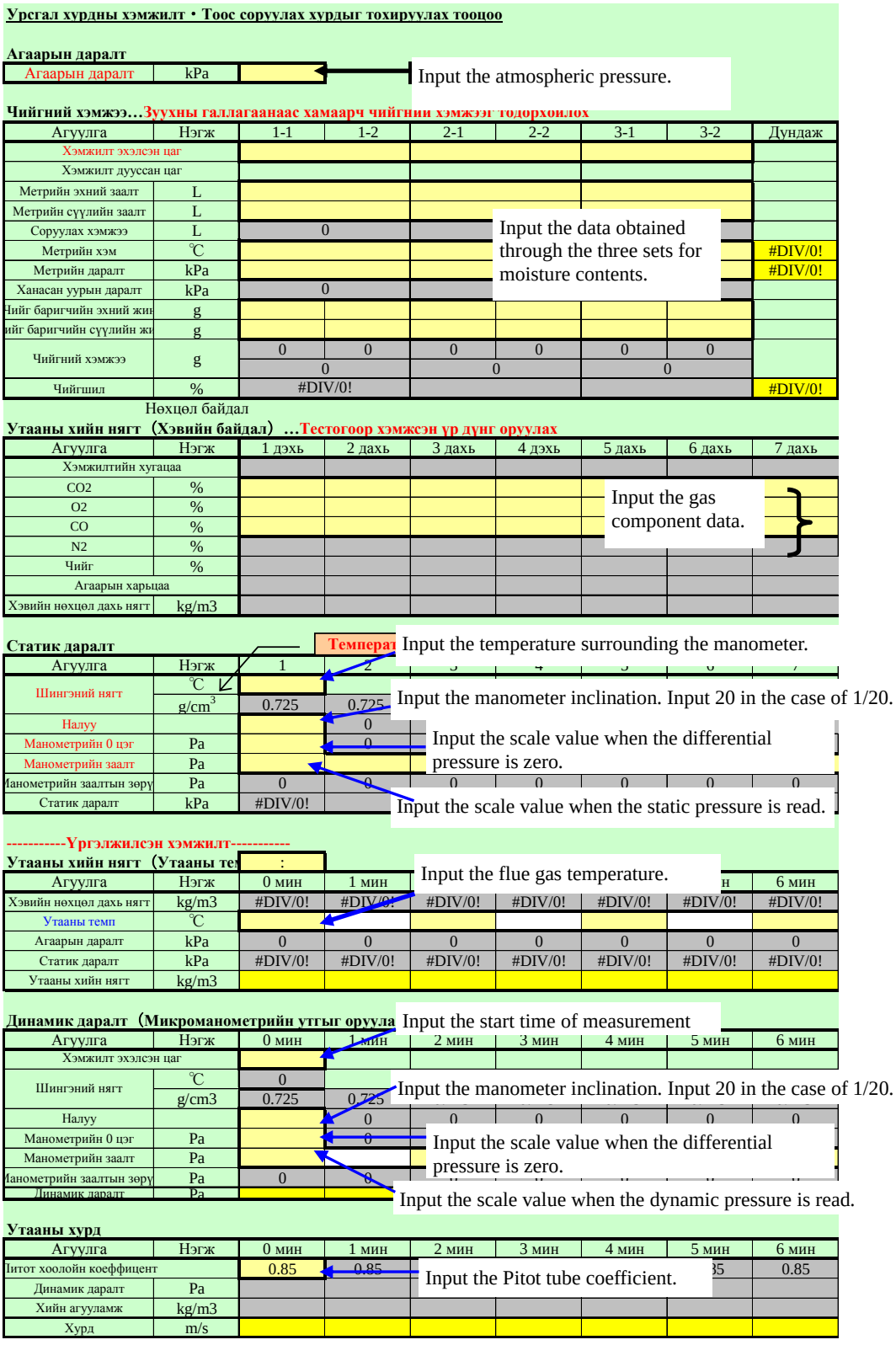
9.1.4. Measurement of the Gas Component

When a chemical sensor-type stack gas analyzer is used, conduct measurement, following the sampling method and procedure specified in 4) of 8.3.2.1. Collect the samples as many as possible for better results. Be sure to collect the data on the gases if high concentrations come out after coal is fed into the stove.

The concentration peak comes differently in time according to the measurement item. Pay attention to the sampling timing.

9.1.5 Input to the Dedicated Dust Calculation Software (Manual)

Input the data collected from 9.1.1 through 9.1.4 to the dedicated dust calculation software.



Урсгал хурдны хэмжилт • Тоос соруулах хурдыг тохируулах тооцоо

Агаарын даралт

Агаарын даралт	kPa	

Input the atmospheric pressure.

Чийгний хэмжээ…Зуухны галлагаанаас хамаарч чийгний хэмжээг тодорхойлох

Агуулга	Нэгж	1-1	1-2	2-1	2-2	3-1	3-2	Дундаж
Хэмжилт эхэлсэн цаг								
Хэмжилт дууссан цаг								
Метрийн эхний заалт	L							
Метрийн сүүлийн заалт	L							
Соруулах хэмжээ	L	0						
Метрийн хэм	℃							#DIV/0!
Метрийн даралт	kPa							#DIV/0!
Ханасан уурын даралт	kPa	0						
Чийг баригчийн эхний жи	g							
ийг баригчийн сүүлийн жи	g							
Чийгний хэмжээ	g	0	0	0	0	0	0	
		0		0		0		
Чийгшил	%	#DIV/0!						#DIV/0!

Input the data obtained through the three sets for moisture contents.

Нөхцөл байдал

Утааны хийн нягт（Хэвийн байдал）…Тестогоор хэмжсэн үр дүнг оруулах

Агуулга	Нэгж	1 дэхь	2 дахь	3 дахь	4 дэхь	5 дахь	6 дахь	7 дахь
Хэмжилтийн хугацаа								
CO2	%							
O2	%							
CO	%							
N2	%							
Чийг	%							
Агаарын харьцаа								
Хэвийн нөхцөл дахь нягт	kg/m3							

Input the gas component data.

Статик даралт

Агуулга	Нэгж	1	2
Шингэний нягт	℃		
	g/cm^3	0.725	0.725
Налуу			0
Манометрийн 0 цэг	Pa		0
Манометрийн заалт	Pa		
Манометрийн заалтын зөрү	Pa	0	0
Статик даралт	kPa	#DIV/0!	

Input the temperature surrounding the manometer.

Input the manometer inclination. Input 20 in the case of 1/20.

Input the scale value when the differential pressure is zero.

Input the scale value when the static pressure is read.

----------Үргэлжилсэн хэмжилт----------

Утааны хийн нягт（Утааны те

Агуулга	Нэгж	:						
		0 мин	1 мин				н	6 мин
Хэвийн нөхцөл дахь нягт	kg/m3	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Утааны темп	℃							
Агаарын даралт	kPa	0	0	0	0	0	0	0
Статик даралт	kPa	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Утааны хийн нягт	kg/m3							

Input the flue gas temperature.

Динамик даралт（Микроманометрийн утгыг оруула

Агуулга	Нэгж	0 мин	1 мин	2 мин	3 мин	4 мин	5 мин	6 мин
Хэмжилт эхэлсэн цаг								
Шингэний нягт	℃	0						
	g/cm3	0.725	0.725					
Налуу			0	0	0	0	0	0
Манометрийн 0 цэг	Pa		0					
Манометрийн заалт	Pa							
Манометрийн заалтын зөрү	Pa	0	0					
Динамик даралт	Pa							

Input the start time of measurement

Input the manometer inclination. Input 20 in the case of 1/20.

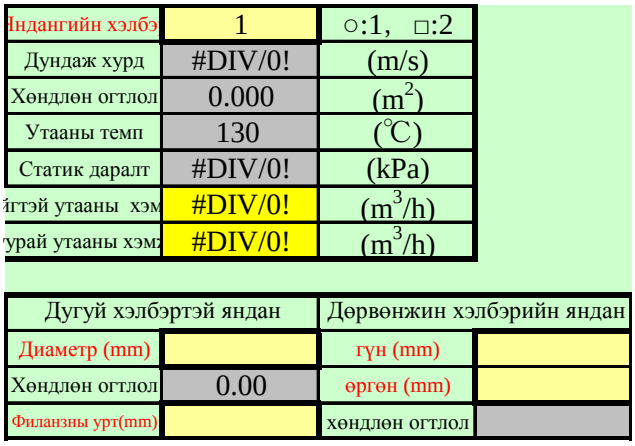
Input the scale value when the differential pressure is zero.

Input the scale value when the dynamic pressure is read.

Утааны хурд

Агуулга	Нэгж	0 мин	1 мин	2 мин	3 мин	4 мин	5 мин	6 мин
итот хоолойн коеффицент		0.85	0.85				85	0.85
Динамик даралт	Pa							
Хийн агууламж	kg/m3							
Хурд	m/s							

Input the Pitot tube coefficient.



Яндангийн хэлбэ	1	○:1, □:2
Дундаж хурд	#DIV/0!	(m/s)
Хөндлөн огтлол	0.000	(m^2)
Утааны темп	130	(℃)
Статик даралт	#DIV/0!	(kPa)
йгтэй утааны хэм	#DIV/0!	(m^3/h)
урай утааны хэм	#DIV/0!	(m^3/h)

Дугуй хэлбэртэй яндан		Дөрвөнжин хэлбэрийн яндан	
Диаметр (mm)		гүн (mm)	
Хөндлөн огтлол	0.00	өргөн (mm)	
Филанзны урт(mm)		хөндлөн огтлол	

Input the data on the stack shape & size and the flange size.

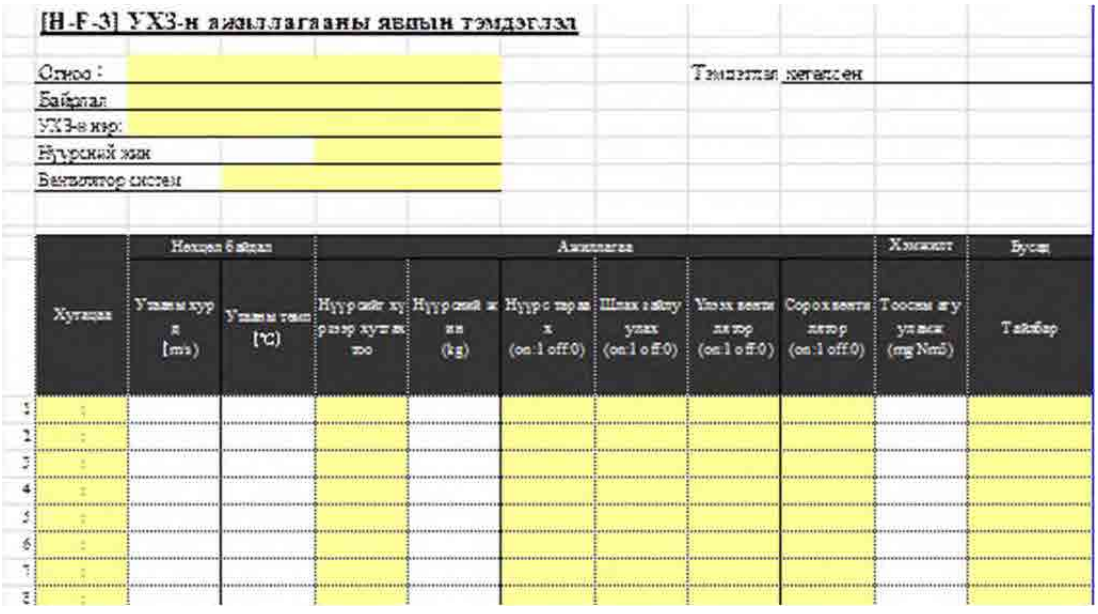
Figure 9-9 Dedicated Dust Calculation Software (For Manual Equipment)

9.2 Recording of the Fed Coals and the Operations of the Stove

The properties of the flue gas are influenced by stove operations such as feeding coal, scraping out and remove ashes.

Start recording these operations, preferably about one hour before the start of the dust sampling (after starting the measurement of the gas component). In addition, the quantity and the color of the flue gas discharged from the stack should be recorded.

Used for a calculation of the emission coefficient, these records are also very useful when you determine the reported value, which is calculated based on the organized data, is valid or not.



[H-F-3] УХЗ-н ажиллагааны явцын тэмдэглэл

Огноо :

Байрлал

УХЗ-н нэр:

Нүүрсний нэр

Вентилятор систем

Тэмдэглэл хөтөлсөн

Хугацаа	Нөхцөл байдал		Ажиллагаа						Хэмжилт	Бусад
	Утааны хурд [m/s]	Утааны темп [℃]	Нүүрийг хувь руугаа хутгасан тоо	Нүүрсний нэмсэн [kg]	Нүүр гарах (on:1 off:0)	Шаар гаргах (on:1 off:0)	Үлэх вентилятор (on:1 off:0)	Сорох вентилятор (on:1 off:0)	Тоосны агуулга (mg/Nm3)	Тайлбар
1										
2										
3										
4										
5										
6										
7										
8										

Figure 9-10 Boiler Operation Recording Sheet

9.3 Dust Sampling (Manual)

Capture the dust on the cylindrical filter, and determine the weight of the captured dust by using the difference between the weight of the cylindrical before sampling and after sampling. This is a method of obtaining a dust concentration from the total volume of gases sampled which are determined by a gas meter. Adopt the isokinetic sampling method enables to capture the dust particles as precisely as possible. For details of the approach, refer to the technical manual.

Follow the procedure below:

(1) Calculate the isokinetic sampling speed with the dedicated dust calculation software.

Open the sheet recording the inputted preliminary measurement results in Section 9.1. For calculation of an isokinetic suction speed, it is necessary to determine the inner diameter of the nozzle attached to the sampling probe first. There are a total of nine nozzles (inner diameters: 4, 6, 8, 10, 12, 14, 16, 18 and 20mm) in the nozzle box.

Figure 9-11 Dust Sampling Nozzles and Filter Holder

The size of nozzle to be used is determined based on the following conditions.

Table 9-1 How to Choose a Dust Sampling Nozzle

No.	Requirements for selection of a nozzle
1	The isokinetic sampling speed is calculated after inputting the selected nozzle inner diameter into the dedicated dust calculation software. This speed must not exceed approximately 25L/min.
2	Choose the nozzle with the largest diameter, satisfying the above.
3	It is acceptable to choose the nozzle with a smaller diameter than that of Item 2 when the sampling time will be extended due to an expected lower dust concentration.

Агуулга	Нэгж	0 мин
Хошууны диаметр	mm	16
Хийн урсгал хурд	m/s	2.71
Чийгний хэмжээ	%	9.84
Метрийн темп	℃	7
Утааны темп	℃	128
Агаарын даралт	kPa	87.7
Статик даралт	kPa	0.001
Метрийн даралт	kPa	0.04
Ханасан уурын даралт	kPa	0
Соруулах хэмжээ	L/min	20.57
Соруулах хурд	sec/L	2.92

According to the table above, the nozzle of 16mm is selected with a calculated suction flow

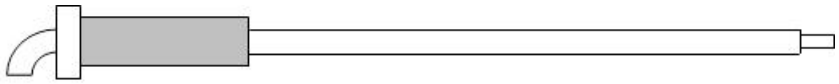
rate of 20.57L/min.

Compared to HOBs, the heat power of Ger stove is very week, once fire dying down, the flow rate of flue gas became slower. If it is less than 4 m/s, accurate monitoring cannot be realized by using Pitot tube, and dust shall not be collected accurately on control of isokinetic dust sampling. Pre-measurement is recommended by hot-wire flow speed meter prior to start the measurement. If it is not possible to take dust sample by isokinetic method, change to constant flow rate sampling method at which the sample gas is sucked by the certain constant sampling speed, however the sampling accuracy became decreased.

If slow flow speed is anticipated for fuel burning in a Ger stove, you may take a dust sample by isokinetic method while burning at strong heat power is expected, and take another dust sample by constant speed sampling in week heat power period.

(2) Take out a new cylindrical filter having a smaller number from the storage case containing filter paper cylinders already weighed, and fix it to the holder. Make adjustment so that the bottom of the filter paper does not contact with the filter holder bottom. Attach the nozzle with a selected inner diameter.

Make sure to place the packing, and tighten the nozzle with the cover ring. Connect the pipe (properly wind sealing tape to prevent leakage).



The following is a conceptual illustration for measurement of the flow rate at the four points in the duct. The tip of the sampling probe is placed at the first point to take the dust sample (the same image as that of the Pitot tube). Mark the sampling positions on the tube with tape (the center of duct is the measurement point for Ger measurement).

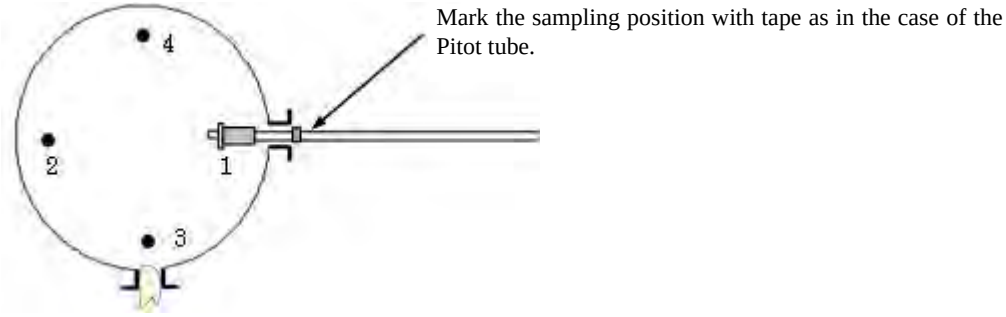


Figure 9-12 Inserting Position of the Sampling Tube with Marking

(3) Setting of the Sampling Tube

Insert the sampling probe prepared in 9.3 into the duct. As the figure below shows, the sampling probe is placed horizontally when the stack is vertical. The sampling nozzle is directed upward until the dust sampling starts. Seal the clearance with heat-resistant tape.

Insert the Pitot tube and the Type K thermocouple together with the sampling probe. Pay attention to where to set them so that they do not interfere with one another to disturb the flow. When the stack is vertical as shown in the figure, the dust sampling probe and the Pitot tube should be set side by side horizontally to prevent disturbance when the stack is placed vertically.

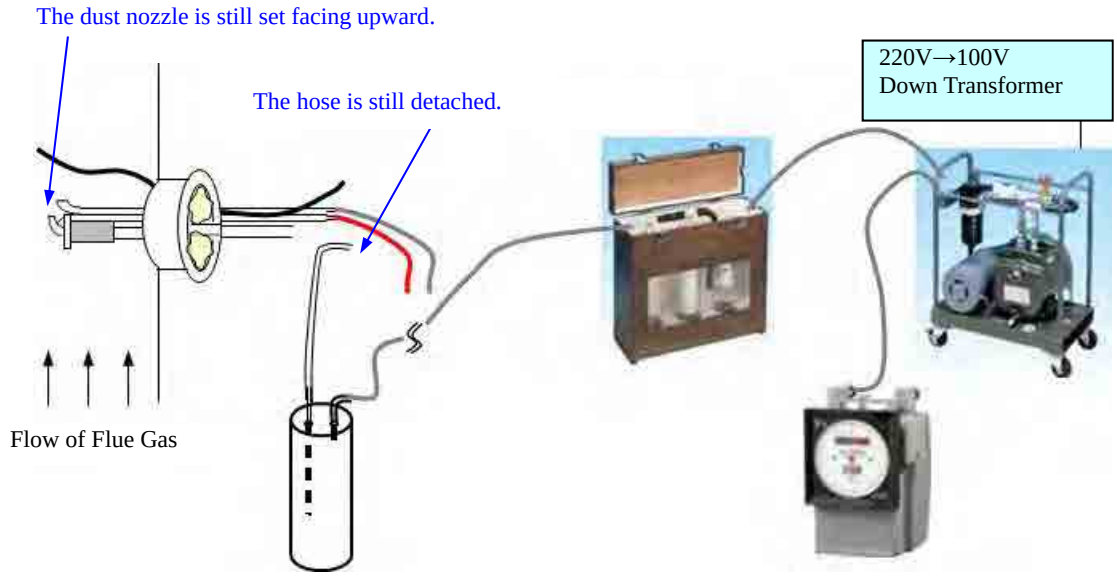


Figure 9-13 Before Dust Sampling

(4) Immediately Before Sampling

Turn on the suction pump temporarily. Adjust the flow control valve of the pump to set the suction flow rate to approximately a calculated value by measuring the rotation of the gas meter. After the adjustment, stop the suction pump. Read the accumulated flow rate of the gas meter, and write it down on the record sheet as the value read before sampling together with the number of the set filter paper cylinder.

(5) Timing of the Sampling

Although a total of three dust samples or more will be collected, the start time and the end time must be decided properly, depending on the operating status of the stove.

The concentration of the stove flue gas significantly changes, depending on the operating condition of the stove. To obtain a representative average, give consideration to the timing of when to conduct sampling. Refer to the “Stack Gas Measurement Protocol.”

(6) Start of the Sampling

Before starting the sampling, connect the hose which has been kept separated. Turn the nozzle properly to be faced with the flow of the flue gas (the angular tolerance is ±5°). Determine the insertion position of the sampling probe in accordance with the tape marked on the sampling probe so that the sampling nozzle is properly located at the measuring point.

Establish the necessary lines for the Pitot tube and the temperature sensor.

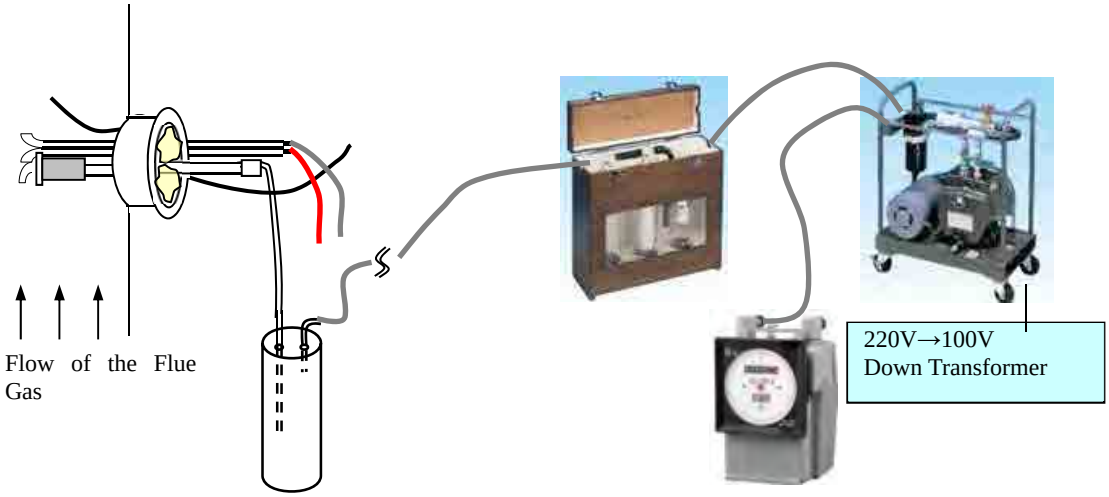


Figure 9-14 Start of the Dust Sampling

Turn on the suction pump to start sampling. Use the walky-talky for smooth communication, when needed.

After start, immediately conduct the following flow rate adjustment operations.

Table 9-2 Procedure for Adjustment of the Suction Flow Rate in Dust Sampling (Isokinetic Suction Control)

No.	Suction Flow Rate Adjustment Procedure
1	Read the current flue gas temperature with the logger, and input it into the dedicated dust calculation software (also on the record sheet).
2	Read the current dynamic pressure with the inclined manometer, and input it into the dedicated dust calculation software (also on the record sheet).
3	Read the temperature and the pressure of the gas meter, and input them into the dedicated dust calculation software (also on the record sheet).
4	Readjust the flow rate control valve again to make the flow rate close to the value automatically calculated with the dedicated dust calculation software.

(7) During the Sampling

Repeat the flow rate adjustment procedure shown in Table 9-2 at an interval of one minutes to maintain the isokinetic suction conditions. It is necessary to repeat the adjustment minutely since the suction rate declines as the cylindrical filter clogs with dust.

Check that the sampling probe is set horizontal correctly at its insertion position.

(8) End of the Sampling

As a rule, conduct the flue gas sampling for 20 minutes per cylindrical filter. When the sampling time is extended further, be careful not to cause clogging in the cylindrical filter (stop sampling immediately when any clogging sign is seen).

Stop the suction pump when the sampling time ends. Pull the sampling probe out of the duct, and collect the cylindrical filter (Photo: Dedicated collecting bottle set). Read the scale of the gas meter, and write it down on the record sheet as the post-sampling value.

Figure 9-15 Collecting Filters after the Sampling

(9) Dust Collection for the Second and Third Sets

After completing the sampling at the first measuring point in (8), repeat the above steps from (1) through (8) for the sampling at the other measuring points. Collect three or more filter paper cylinders per stove.

10. On-site Measuring Work 2 (with Automated Equipment)

For the use of the automated equipment, it is unnecessary to conduct a preliminary measurement required for the manual equipment as shown in the process of the Figure 6-2. Immediately after installing the necessary equipment and observing the flue gas temperature and the flow speed for a short time, you can start an automatic measurement.
The automated dust sampler has a Type K thermocouple and a Pitot tube, which are attached to its sampling probe. Its design allows to collect necessary data such as the temperature and pressure (flow speed) of the flue gas while sampling dust.
The continuous stack gas analyzer shown in 8.3.2.2 and 8.3.3 collects the gas component data. The moisture data is collected in the same manner as the manual equipment. However, the moisture sampling is conducted simultaneously with the dust sampling.

10.1 Measurement of the Gas Component (Automatic)

As specified in 2) of 8.3.3, the continuous stack gas analyzer must be installed and started earlier than other equipment. After warming-up the analyzer, make calibration using standard gases.

10.1.1 Calibration of the Continuous Stack Gas Analyzer

Calibration is a must to be conducted prior to the measurement with the stack gas analyzer on the day of a measurement.
After warming up the stack gas analyzer and confirming its normal operation, start collecting the necessary data with the logger.
Connect the cylinder filled with the standard gas to the standard gas inlet of the stack gas analyzer, and introduce the standard gas flow into the analyzer with the specified pressure. Adjust the sensitivity for each measurement item.
In the case of gas analyzers made in Japan, they differ from one another about how to introduce the gas into the analyzer (refer to the figures below). Never apply pressures exceeding the atmospheric pressure to the analyzer which designed to introduce the gas at atmospheric pressures.

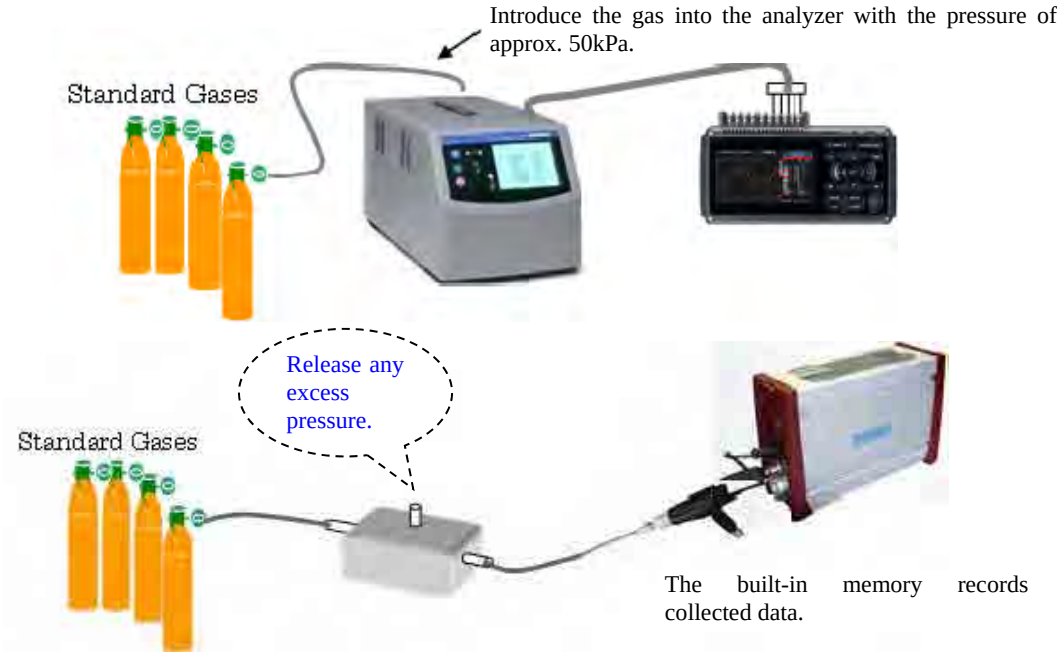


Figure 10-1 Introduction of the Standard Gas to Continuous Stack Gas Analyzers Made in Japan

The following types of standard gasses are available. Be sure to use the gasses whose validity term is guaranteed by manufacturer.

Table 10-1 Types and Concetrations of the Satndard Gasses for a Analyzer (Example)

Zero Gas	N2 Gas (Purity: 99.9999% or more)
Span Gas	SO2／N2 190ppm
	NO／N22 190ppm
	CO／N22 190ppm (for low concentration), 4% (for high concentration)
	CO2／N2 14.5%
	O2／N2 21.5%

The fundamental procedure for calibration is as follows. Conduct the span calibration following the zero calibration. It is enough to conduct these two points calibration. For the operational procedure of the equipment, refer to the technical manual.

Tbale 10-2 Calibration Procedure for a Stack Gas Analyzer

Zero Calibration	Introduce the N2 gas of a specified pressure into the analyzer through the standard gas inlet.
	Continue feeding the gas into the analyzer for one minute or more. Watching the concentration graph indicated on the logger, confirm that the indication is stabilized (in each measurement item) and the concentration is close to zero.
	Conduct the zero calibration. Do not make a too rough calibration.
	Keep the calibration coefficients on record.
Span Calibration	Introduce the standard gas of a specified pressure into the analyzer through the standard gas inlet.
	Continue feeding the gas flow into the analyzer for one minute or more. Watching the graph indicated on the logger, confirm that the indication is stabilized (in each measurement item) and the concentration is close to the level indicated on the cylinder.
	Conduct the span calibration. Do not make a calibration exceeding 2%.
	Keep the calibration coefficients on record.
	Finish the calibration. Return to the normal measurement mode.

10.1.2 Start of the Gas Component Measurement

Reconnect the piping as illustrated in 8.3.3 to start the flue gas measurement in accordance with the following procedure. Complete the operations up to this step while making preparations for the dust and moisture sampling equipment.

(1) Confirm that the equipment is collecting the data with the logger and the built-in memory.

(2) Start the suction pump. Confirm that the excess flue gas is sufficiently released from the manifold just behind the pump.

(3) Observe that the concentration indicated on the stack gas analyzer is approaching the

concentration of the flue gas. When the indicated oxygen level is around 19%, attention is required for the possibility that the line may have leaks or be clogged.

(4) Maintain this monitoring (keep monitoring until dust and other sampling operations are completed).

(5) Watch how the concentration indicated with the logger graph changes from time to time. Carefully observe that operational changes in the stove such as coal feeding are properly reflected in the indication.

(6) Confirm that the readings of measurement by the two measuring units for high and low concentrations are close to each other.

10.2 Preparation Work (Automatic)

Like the manual type equipment, 8.3 “Installation and Warming up of the Equipment” and 8.4 “Checks after Installation” are also required for the automated equipment operation. After finishing these steps, make preparations for the dust and moisture sampling.

10.2.1 Preparations for the Moisture Measurement

Implement the steps from (1) through (5) of 9.1.3.

10.2.2 Preparations for the Dust Sampling

For the automated dust sampler, conduct the following check operations.

1) Checking leaks from the piping

Like the manual sampler, conduct checking in accordance with 8.4.2.1, but do not connect the piping to the automatic controller main body (see the figure below), to protect the inside delicate pressure sensor from pressure shock during leak check.

For the line on the stack side, confirm that there are no leaks by sucking the line with your mouth.

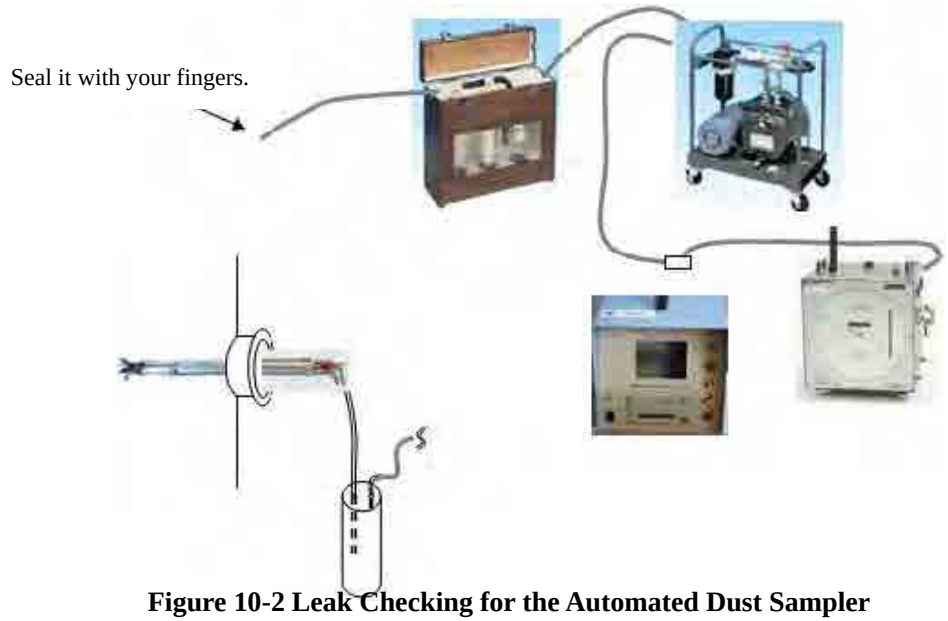


Figure 10-2 Leak Checking for the Automated Dust Sampler

2) Checks of the Controller Main Body

After turning on electricity, check in accordance with the table below.

Table 10-3 Movement Checks for the Automated Dust Sampler

Check Item	Detailed Checking
Time	Confirm that the current indicated time is correct.
Zero Adjustment for the Manometer	Remove the sampling tube and connecting pipings (in 4 colors) from the equipment back. Press the "0-ADJ" button on the front under the condition that the same pressure (atmospheric pressure) is applied to the four ports. Zero adjustment is conducted for the manometer.  Prevent these four ports from being affected by a wind. Do not seal them with your fingers (because excess pressure is applied to their inside). (For checking of the isokinetic sampler pressure sensors) After inputting 1 as the Pitot tube coefficient and 6 mm as the nozzle diameter on the screen, apply the same pressure to the red and yellow pipe. When the dynamic pressures of the two sensors are indicated as a same Pa value, the pressure sensors are normal.
Interlocking with the Suction Pump	Be sure to turn on the suction pump and manually turn the pump flow control valve almost fully opened (when much air is not fed to the main body from the pump, the flow rate control in the main body will be delayed with difficulty of operation). Confirm that the controller will automatically regulate the flow rate even if the flow control valve is manually turned to a certain position.
Printed letters of the Printer	Pull out the printer paper holder to confirm that enough paper remains. Check that the printed letters are clear and the printer starts printing at the set intervals. Also check that the necessary data is output onto the paper.

3) Confirmation of the Flue Gas Temperature and Flow Speed

Complete the connections of the equipment. Then, insert the sampling probe with no dust sampling filter into the measurement hole. Keep monitoring the flue gas pressure and temperature in the duct which are indicated on the screen of the automated dust sampler.

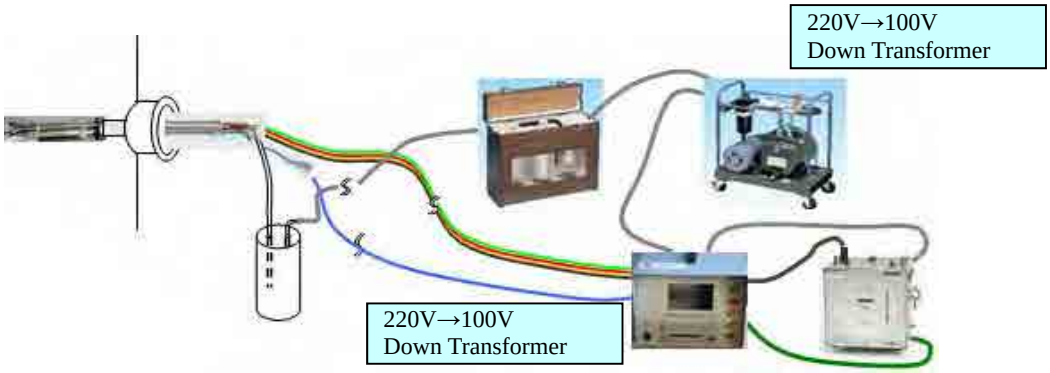


Figure 10-3 Confirmation of the Flue Gas Conditions

4) Setting of the Parameter

While checking the flue gas conditions in a simplified manner in 3), set the parameters with the controller main body. For the procedure, refer to the technical manual.

Parameter Setting	In accordance with the technical manual, conduct the "selection of the parameter and input of the values" on the screen. (Type of the fuel in use, shape of the duct, sampling method, filter attachment position, shape and material of the filter, Pitot tube coefficient, type of the gas meter, measuring method, length of the sampling time or total volume of the sampling gas, time intervals of the printer output, anticipated moisture concentration, and nozzle inner diameter)

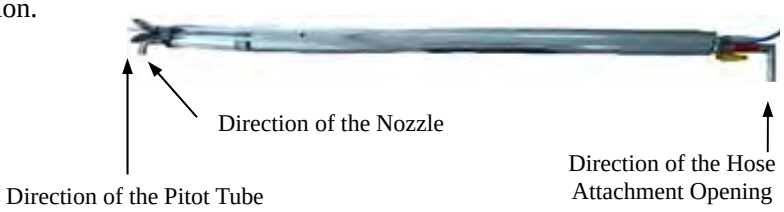
The selection criteria for a sampling nozzle diameter are the same as shown for the manual sampler. Compared to HOBs, the heat power of Ger stove is very week, once fire dying down, the flow rate of flue gas became slower. If it is less than 4 m/s, accurate monitoring cannot be realized by using Pitot tube, and dust shall not be collected accurately on control of isokinetic dust sampling. Pre-measurement is recommended by hot-wire flow speed meter prior to start the measurement. If it is not possible to take dust sample by isokinetic method, change to constant flow rate sampling method at which the sample gas is sucked by the certain constant sampling speed, however the sampling accuracy became decreased. If slow flow speed is anticipated for fuel burning in a Ger stove, you may take a dust sample by isokinetic method while burning at strong heat power is expected, and take another dust sample by constant speed sampling in week heat power period.

After completing the setting, take out the sampling probe from the measurement aperture.

5) Attachment of the Filter Head

How to set the filter paper is almost the same as 9.3. Set the nozzle with the selected inner diameter.

Attach the filter head to the sampling probe to constitute a complete unit. Adjust the positions so that the Pitot tube, the dust nozzle and the suction hose attachment opening are in the same direction.



10.2.3 Assembly of the Equipment on the Stack Side

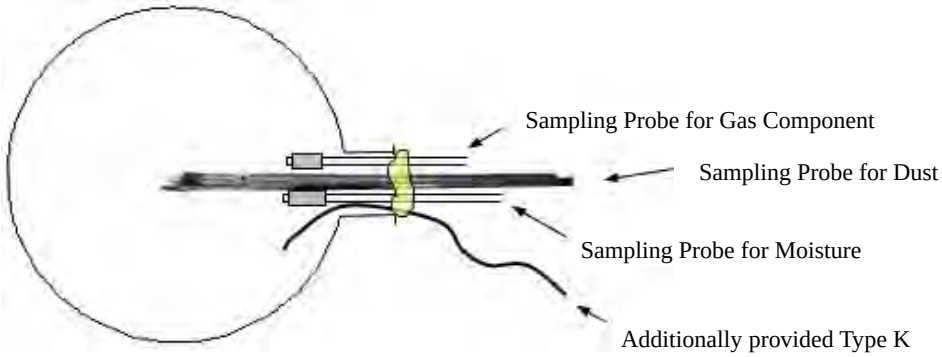


Figure 10-4 Sampling Tubes Inserted into the Measurement Hole (Duct Sectional View)

For sampling, set a sampling probe at the measurement hole. As shown in the figure below (sectional view of the duct) shows, how to set the three sampling tubes and the temperature sensor, in addition to the sampling probe for gas component under measurement. The figure below illustrates a case where the inner diameter of the duct is small and dust sampling is made at one point, in the center of the duct.

10.2.4 Immediately before Starting the Sampling

Next, complete the moisture sampling line by following the steps of (6) and (7) of 9.1.3. Read the moisture gas meter before sampling, and write it down together with the Shefield bottle numbers on the record sheet.

In addition, complete the dust sampling line as shown in the Figure 8-13 (the dust nozzle must not face the flow of the flue gas before sampling). Write down the read value of the dust gas meter before sampling, and write it down along with the number of the attached filter on the record sheet (read the value with your eyes, although the automated dust sampler automatically measures the accumulated suction volume).

Figure 10-5 Installed Equipment on the Stack Side (For the Automated Equipment)

Figure 10-6 Monitor Side Prepared for the Sampling

Like the manual equipment, confirm that the facility information record sheet and the measurement data record sheet shown in the Figure 7.2 are filled out with necessary information.

10.3 Sampling of Dust and Moisture (Automatic)

In principle, dust and moisture must be collected in the same timing and for the same length of time for the automated equipment.

10.3.1 Start of the Sampling

After confirming that the necessary lines are all connected, start the moisture and dust sampling at the same time. The main procedure is indicated in the table below.

Table 10-4 Sampling Start Procuedure for the Automated Dust Sampler

Item	Work Description
Dust Sampling	Turn the dust sampling nozzle in the same direction against the flow of the flue gas.
	Turn on the suction pump switch and the start button of the controller main body.
	Write down the sampling start time on the record sheet.
	The indication of the main body screen changes to “Under Measurement.”, Automatic control of the gas suction speed starts. The values of the “Flue Gas Dynamic Pressure Pd” and “Suction Gas Differential Pressure Vd” indicated on the screen become close to each other. When they are almost the same, the isokinetic sampling comes into effect.  Then, sampling goes on under the automatic control.
	Confirm that the indicated flue gas temperature accords with the value of the other temperature sensor indicated on the logger.
	Check the setting condition of the sampling probe on the stack side and the condition of the trap bottle again.
	Check the set parameters again.
Moisture Sampling	Same operation as the manual type equipment: Follow the step (9) of 9.1.3. However, it is possible to decrease the suction flow rate to around 0.5L/min.
	Write down the sampling start time on the record sheet.

For the continuous stack gas analyzer, watch how the concentration changes again referring to the logger graph indication.

Check that the indicated values of the measuring equipment for high concentration and for low concentration become close to each other.

10.3.2 During the Sampling

The check points for the moisture sampling are the same as (10) of 9.1.3.

The check points for the dust sampling are almost the same as (7) of 9.3. The isokinetic sampling controlled by the automated equipment is different from the manual type equipment.

As shown in Table 10-4, confirm that the dust sampling is automatically controlled under the isokinetic sampling conditions. The automated sampler prints the control and other conditions with the printer at the set intervals. Regularly check that there are no abnormalities.

Even under the automatic control, isokinetic sampling sometimes does not work. In that case, it is necessary to manually operate the flow control valve of the pump so as to return it to the position easy to control. This happens due to any extreme flue gas condition at the site such as the flow speed drastically fluctuating or due to the low flow speed, to which the controller cannot properly respond. If the suction rate extremely goes to the maximum or the minimum under the out-of-control condition, the BZ lamp lights and the buzzer sounds. In this case, operate the flow control valve immediately so as to return it to the position where the automatic control works.

10.3.3 End of the Sampling

The steps for the moisture sampling are the same as (11) and (12) of 9.1.3. Sampling of moisture contents is finished at the same time when dust sampling is complete.

When the sampling flow rate (or time) designated through the parameter setting reaches the target, the equipment automatically finishes the sampling and the stop lamp lights (but manually turn off the suction pump when the pump is plugged into a different power outlet from that of the main body).

Pull out the sampling probe from the duct, and collect the first cylindrical filter like the manual sampling. Read the gas meter, and write it down on the record sheet as the value after sampling.

10.3.4 Sampling of the Second and Third Sets

The procedure for the automated equipment is the same as that for the manual equipment. Conduct the second and third moisture samplings in the same timing as the dust sampling.

After completing the first dust sampling, repeat the above steps of “3) through 5) of 10.2.2, 10.2.3 and 10.2.4,” and start the next sampling. Use three cylindrical filters or more per stove.

11. Completion of the Entire Monitoring and Pullout

After collecting three samples each for dust and moisture, complete the entire monitoring, following the procedure specified in the table below. The operations which differ between the manual equipment and the automated equipment are shown separately. For the removing the equipment, bring back the equipment to the vehicle, following the installation procedure in the reverse order. Be sure to pay attention to the safety during the operation.

Table 11-1 Operations to Finish the Entire Monitoring (Automatic)

<table>
<tr><th rowspan="2">Item</th><th colspan="2">Outline of the Operations</th></tr>
<tr><th>For the Manual Equipment</th><th>For the Automated Equipment</th></tr>
<tr><td rowspan="2">Gas Component Sampling</td><td colspan="2"><For the Chemical Sensor-type Gas Analyzer>
(1) After analyzing the sample gas, let normal air flow through the analyzer to prevent the sensor from deteriorating. The purging time differs according to the type of analyzed gas and the length of analysis time (refer to the manual). For purging, the longer the better.
(2) Turn off the measuring equipment to place them in their cases. Confirm that analyzed values are output on the record sheet.
(3) Pull out the sampling probes from the measurement hole, and put them in their dedicated case together with the main body.</td></tr>
<tr><td colspan="2"><For the Continuous Stack Gas Analyzer>
(1) Leave the sampling probe pulled out of the measurement hole on the floor until it gets cool.
(2) Stop the suction pump. Let the atmospheric air flow through the analyzer for several minutes.
(3) Complete the data recording with the logger and the memory. Then, transfer the recorded data from the logger to a USB.
(4) Operate the analyzer and the logger to stop them in accordance with the technical manual. Detach the signal lines and the power cables.
(5) Pipings: Purge water if there is any inside. Roll them for pickup.
(6) Put back other equipment in their dedicated cases.</td></tr>
<tr><td>Moisture Sampling</td><td colspan="2">(1) Pull out the sampling probe from the measurement hole. Put back the Shefield bottles into the case.
(2) Confirm that all necessary monitoring records are output on the record sheets.
(3) Detach the pipings from the gas meter, the pump and other apparatuses to put them back into the shelf and the storage boxes. Be careful not to break their glass parts.</td></tr>
<tr><td rowspan="3">Dust Sampling</td><td colspan="2">(1) Confirm that the dust-sampling cylindrical filters are placed in the storage box.</td></tr>
<tr><td>(2) (None)</td><td>(2) You may turn off the power soon after the equipment finishes automatic sampling.
Collect the paper sheets output from the printer (record the place and the date).</td></tr>
<tr><td colspan="2">(3) Confirm that all necessary monitoring records are output on the record sheets.
(4) Put back the sampling nozzle into the case, and check that all nozzles are in place. Clean up dirty nozzles, if any.
(5) Remove any dust from the surface of the detached sampling probe to put it back into the dedicated case.
(6) When the wet type gas meter is used, take out antifreeze from the inside (to return it into the container).
(7) Put back the gas meter and other apparatuses into their dedicated cases.
(8) Pipings: Remove water if there is any inside. Roll them for pickup.</td></tr>
<tr><td>Others</td><td colspan="2">(1) Confirm the on-site data documents such as “record sheets, memories collecting data, and output paper sheets from the printer,” and take them back to the office in one lump.
(2) Take away the pipes, the thermocouple, the sampling tube and others from the measurement hole. Fix the cover placed on the hole with screws.</td></tr>
</table>

	(3) Return the provided power cables and any other articles to the facility, if any. (4) Load all equipment you brought to the site onto the vehicle. Check each of them for confirmation so that nothing is left behind. (5) Clean up the monitoring site, and bring back all refuse to the office. (6) Report to the Ger owner that the monitoring is completed, and go back to the office. (7) After returning to the office, unload the equipment and samples to place them in the equipment room on that day.

Figure 11-1 Pullout Scenes

12. Storage of the Equipment and Samples

When returning to the equipment room, complete the following operations on that day.

(1) Put back the equipment into the shelf or in their original places.

Conduct maintenance for necessary equipment on the same day if it is minor work. If their maintenance requires much time, mention it in a notebook so that the maintenance work will be done at a later date.

Figure 12-1 Storage of Equipment

(2) Put the record sheets and the printer record sheets of the automated dust sampler you brought back to the office into the dedicated file.

(3) Transfer the cylindrical filters for dust sampling from the storage container to the desiccator (check the post-measurement weight at a later date, following the procedure specified in Table 7-3). For the data reduction procedure, refer to the technical manual.

(4) Tell the superior that all work is completed, and this is the end of all operation.