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Oil and gas industries including lower carbon energy — Fuel ammonia —Requirements and guidance for boilers for power generation

Industries du pétrole et du gaz, y compris les énergies à faible teneur en carbone — Ammoniac combustible — Exigences et recommandations applicables aux chaudières pour la production d'électricité

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Foreword

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This document was prepared by Technical Committee ISO/TC 67, *Oil and gas industries including lower carbon energy*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Ammonia can be used as a carbon-free fuel with the potential to contribute to the transition to a carbon-neutral society. The greatest advantage of ammonia is that it does not produce CO_2 during combustion. In addition, the technology for safely liquefying, transporting and storing ammonia has already been implemented in the society as existing ammonia infrastructure; and further development is underway from the perspective of unprecedented large-scale transporting and storing. Appropriate use of these technologies can lead to rapid decarbonization.

There are many potential applications of fuel ammonia, such as boilers for power utility or industrial boilers, gas turbines, marine engines, industrial furnaces, both for new boilers and modified existing facilities. However, from the perspective of achieving carbon net zero, it is necessary to accelerate the application of fuel ammonia to boilers that generate particularly high amounts of CO_2 and other potential greenhouse gases (GHG).

In order to contribute to CO_2 and other potential GHG reduction at an early stage by using fuel ammonia in power generation boilers, there's an urgent need to provide requirements and guidance for manufacturers of ammonia-fired boilers. Demonstration projects of ammonia-fired boilers are progressing successfully; and commercialization is sooner than originally expected. Therefore, it is necessary to establish standards to validate the certainty of design, engineering and manufacturing in terms of envisioned improvement in environmental performance of the electric utility power boilers. This document aims to standardize the functional tests and acceptance tests to be performed in order to accomplish such validation.

Oil and gas industries including lower carbon energy — Fuel ammonia —Requirements and guidance for boilers for power generation

1 Scope

This document specifies requirements and guidance for manufacturers of ammonia-fired boilers regarding functional tests performed at the time of design and on-site acceptance tests, in order to meet the required environmental performance.

This document stipulates the test methods, the measurement items, the evaluation methods and the test reports for each test.

This document is applicable to:

a) land boilers used for power generation with an electrical output of 100 MWe or more;

b) equipment that uses NH_3 of any mixing ratio as fuel;

c) boilers with burners for combustion of fuel.

This document does not apply to heat recovery steam generators for gas turbines, fluidized bed boiler, stokers, black liquor recovery boiler and process heat transfer equipment (used in petroleum refining).

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
acceptance test
test performed at the actual ammonia-fired *boiler* (3.4), prior to the commercial operation date

3.2
fuel ammonia
NH_3 utilized as a fuel for *boilers* (3.4)

Note 1 to entry: Ammonia is used differently as "NH_3", because NH_3 is an expression of a substance with a molecular formula and ammonia is defined as a fuel that includes the concept of purity of NH_3.

3.3
ancillary equipment
series of equipment installed at the downstream of the *boiler* (3.4)

EXAMPLE Denitrification equipment, air preheater, dust removal equipment and desulfurization equipment.

3.4
boiler
equipment generating steam by firing fuels

3.5
burner
device or group of devices for the introduction of fuel and air into a *combustion chamber* (3.7)

3.6
combustion air temperature
temperature of the air introduced into *burners* (3.5) to combust fuels

3.7
combustion chamber
part of the *boiler* (3.4) equipped with *burners* (3.5) where fuels are combusted

3.8
excess air ratio
ratio of the actual combustion air quantity to the theoretically required air quantity to combust fuels completely

3.9
functional test
test performed using the combustion test facility, prior to the fabrication of the electric utility power boilers

3.10
holding time
period required for the establishment of a steady-state operation, before the start of the *functional test* (3.9) or the *acceptance test* (3.1)

Note 1 to entry: This excludes transient time.

Note 2 to entry: See Figure 3.

3.11
land boiler
stationary *boiler* (3.4) installed on land

3.12
manufacturer
supplier or vendor of the ammonia-fired boiler according to the contract with the *purchaser and/or user* (3.17)

3.14
measurement interval time
period between measurements during steady-state operations under the same load condition

Note 1 to entry: See Figure 3.

3.15
multi-stage combustion air port
additional air port installed above or around *burners* (3.5)

3.16
nominal rated heat input
numerical value obtained by multiplying the fuel heating value by the maximum fuel flow rate

Note 1 to entry: This value represents the capacity of the combustion test facility.

3.17
purchaser and/or user
individual or organization that buys, owns, operates, or any combination of functions with respect to the electric utility power *boiler* (3.4) including the ammonia-fired boiler and makes the contract with the *manufacturer* (3.12)

3.18
representative point
predetermined point considered to represent the *spatial average value* (3.20) of the gas concentration and where the measurement will be conducted

3.19
selective catalytic reduction
SCR
denitrification equipment to reduce NOx in the flue gas

3.20
spatial average value
arithmetic mean value obtained from multiple measuring points in the cross section

3.21
steady-state time
period covering all measurement(s), including interval(s) between multiple measurements, and any additional time the equipment is continuously operated for observation purposes under the same load condition

Note 1 to entry: See Figure 3.

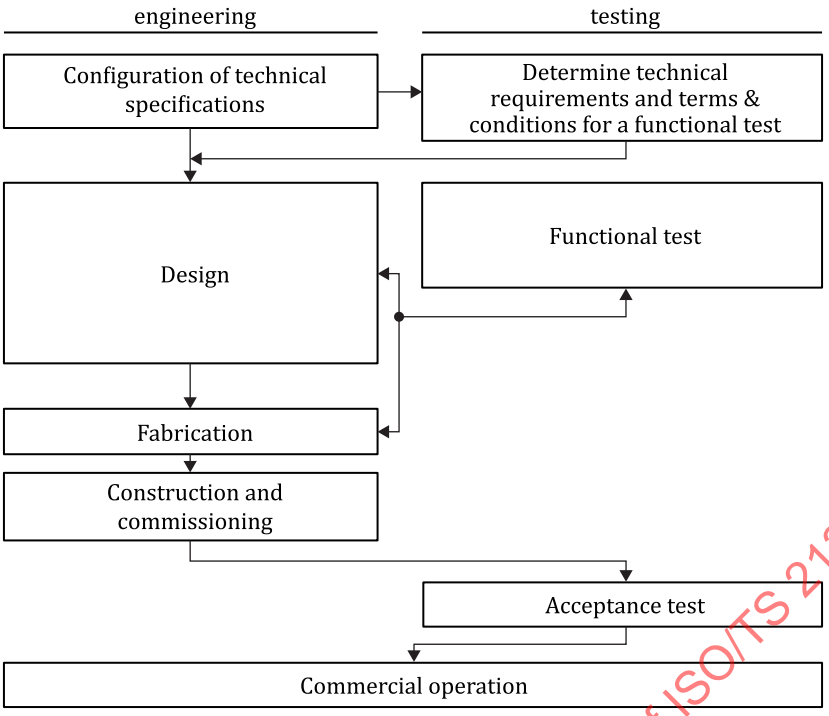
4 General test requirements

4.1 Basic concept of tests

The tests of ammonia-fired boilers shall be carried out in accordance with Clause 5 (functional test) and Clause 6 (acceptance test). Figure 1 indicates an entire typical process, its main activities including functional test and acceptance test, and the correlations between activities.

Functional tests are performed by the manufacturer at smaller-scale test facilities with the aim of achieving such design that fulfils the purchaser and/or user's environmental performance requirements specifically in terms of levels of emissions of GHG and other flue gas emissions that are recognized as environmental pollutants. The purpose of functional tests is to verify the validity of the design in order to proceed to detailed design to reduce the risk of an acceptance test failure. The concept of the purchaser and/or user's performance requirements is shown in Annex A.

Acceptance tests are conducted at the purchaser and/or user's installation site with the aim of confirming the levels of emissions of GHG and other flue gas emissions that are recognized as environmental pollutants as agreed between the purchaser and/or user and the manufacturer. The procedure of acceptance tests shall be agreed upon in writing between the concerned parties.

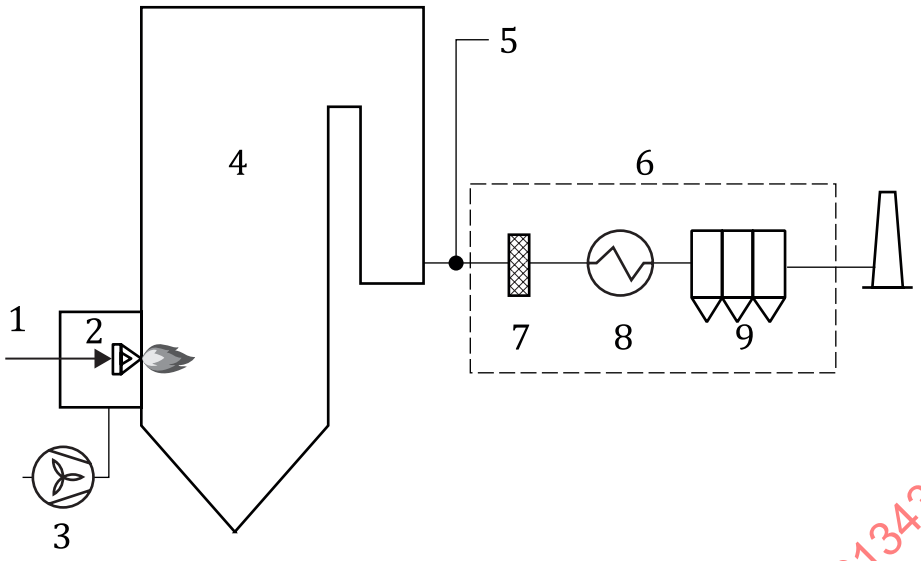


NOTE The order is an example.

Figure 1 — Entire typical process, its main activities including functional test and acceptance test, and the correlations between activities

4.2 Extent of test

The concept of an ammonia-fired boiler is illustrated in Figure 2, which shows ammonia as a fuel, a combustion chamber, a flue gas measurement point and downstream flue gas treatment facilities. The tests shall be conducted on ammonia-fired boilers, both for new power plants and modified existing facilities.



Key

1	NH_3 as fuel of any mixing ratio	6	ancillary equipment
2	burner	7	selective catalytic reduction (example)
3	fan	8	heat exchanger (example)
4	combustion chamber (at functional test) or boiler (at acceptance test)	9	precipitator (example)
5	flue gas composition measurement position		

NOTE Ancillary equipment varies among test facilities.

Figure 2 — Conceptual diagram of test facilities

5 Functional test

5.1 General

If a valid test report that demonstrates the required performance of the purchaser and/or user exists, that shall be acceptable and included in the functional test report. Otherwise a functional test shall be carried out in accordance with the specification.

A functional test shall be performed by the manufacturer prior to fabrication of the electric utility power boilers with the test equipment (see Figure 2) and test methods described in 5.3. The test results shall be reported to the purchaser and/or user in accordance with the functional test report as described in 5.5.

The manufacturer may also outsource the tests as necessary.

5.2 Measurements for functional test

The concentration of the following combustion emissions shall be measured in the functional tests. Regarding the required performance of combustion emissions for electric utility power boilers as agreed with the purchaser and/or user, it shall be verified whether the values corrected for electric utility power boilers based on the measurement results from the functional tests satisfy the required performance, and that information shall be reported in the functional test report. In addition to GHG and other environmental pollutants, levels of poisonous substances such as HCN should be measured:

— NOx;

— NH_3;

— N_2O;

— unburned fuel.

5.3 Functional test equipment

5.3.1 General

The test facility for functional test of ammonia-fired boilers shall be equipped with the following facilities (ancillary equipment varies among test facilities):

— a combustion chamber with a nominal rated heat input of at least 0,5 MWth equipped with a-burner able to fire ammonia as either a single fuel or in mixtures, or both;

— a combustion emissions measurement equipment installed between the combustion chamber outlet and the inlet of the ancillary equipment, with a measurement installation at a well-mixed location; the measurement equipment may be permanent or temporary, on-site or off-site.

5.3.2 Ammonia combustion burner

The system shall be capable of burning fuel ammonia alone, or fuels other than fuel ammonia simultaneously or alternately. The burner structure shall be equivalent to that of electric utility facilities. The test facility shall be capable of evaluating the purchaser and/or user's performance requirements of electric utility facilities.

5.3.3 Combustion chamber

The combustion chamber used for the functional test shall be equipped with functions equivalent to those of electric utility facilities that can effectively suppress the generation of nitrogen oxides and unburned NH_3 by injecting the appropriate amount of air that is necessary for fuel combustion. Examples of functions equivalent to those of electric utility facilities may include but are not limited to a low NOx burner and multi-stage combustion air ports that suppress the generation of nitrogen oxides and unburned NH_3.

5.3.4 Combustion emissions measurement equipment

Measurement equipment shall be installed between the outlet of the combustion chamber and the inlet of the ancillary equipment with a measurement installation at a well-mixed location, and shall be capable of measuring and indicating the measurement items described in 5.2 (see Figure 2).

5.4 Method for functional test

5.4.1 Fuel

The fuel ammonia used for the functional test shall be either a gas or a liquid, containing at least 99,5 % NH_3 (mass fraction) regardless of the mixing ratio.

The fuel used for the functional test should be equivalent to that used in electric utility power boilers which the purchaser and/or user is expected to install.

NOTE 99,5 % NH_3 is the purity that is currently commercially available.

5.4.2 Test condition

The operating conditions of the electric utility power boilers shall be taken into account when carrying out combustion in the functional test, including the pressure and temperature of the fuel ammonia supplied to the burner, the combustion air temperature and the excess air ratio.

5.4.3 Measurement method

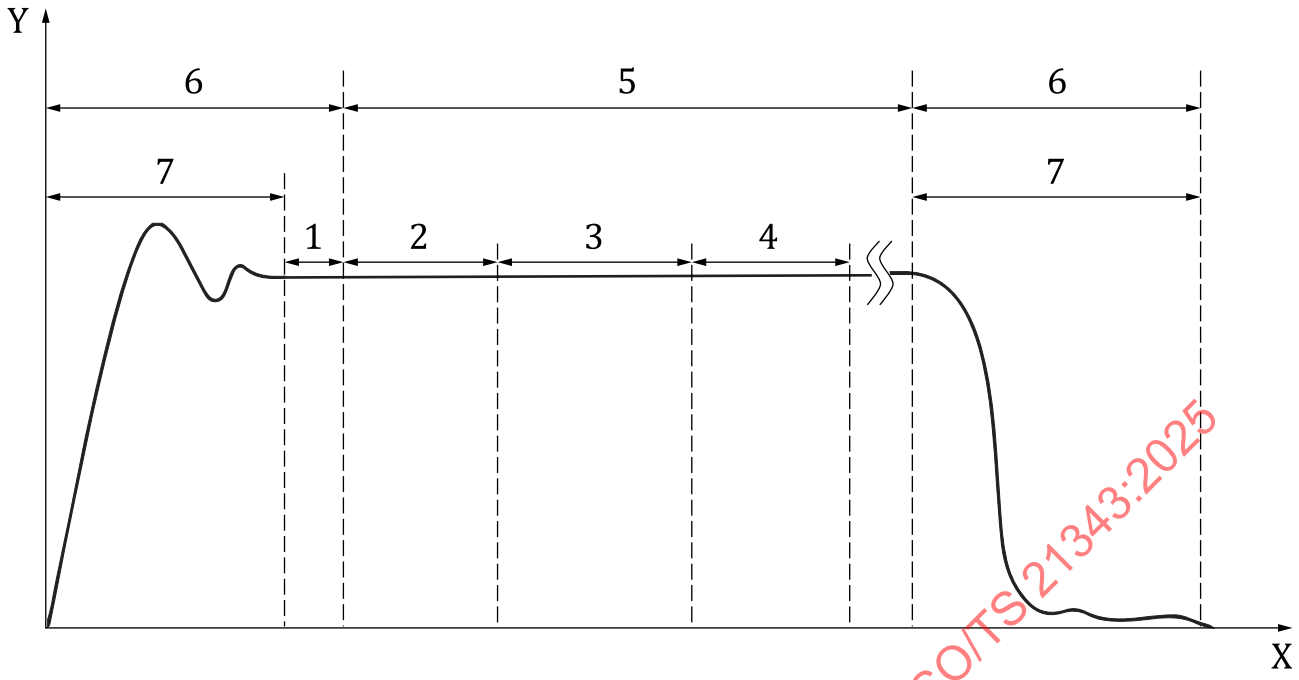
After the test conditions are established and stabilized, the holding time and measurement interval time shall be secured (see Figure 3). If there are multiple test conditions, the holding time and interval time shall also be secured each time. The measurement point(s) shall be at locations from the chamber outlet, at a representative point or a suitable grid measurement where a uniform flow is expected. The measurements in the functional tests for the measurement items in 5.2 should be performed according to the following.

a) NOx: NOx concentration should be measured automatically and continuously between the outlet of the combustion chamber and the inlet of the ancillary equipment (see Figure 2), with a measurement installation at a well-mixed location, by establishing a representative point that indicates the spatial average value in the cross section. The representative point is determined in advance by measuring all points in the duct cross-section at the rated output. At partial load, the representative point is used. As an example, a measurement method in accordance with ISO 10849 is deemed appropriate. Alternatively, a full grid measurement can be carried out.

b) N_2O: N_2O concentration should be measured between the outlet of the combustion chamber and the inlet of the ancillary equipment (see Figure 2), with a measurement installation at a well-mixed location, by establishing a representative point that indicates the spatial average value in the cross section. The representative point is determined in advance by measuring all points in the duct cross-section at the rated output. At partial load, the representative point is used. As an example, a measurement method in accordance with ISO 21258 is deemed appropriate. Alternatively, a full grid measurement can be carried out.

c) NH_3: NH_3 concentration should be measured manually in batches between the outlet of the combustion chamber and the inlet of the ancillary equipment (see Figure 2), with a measurement installation at a well-mixed location, by establishing a representative point that indicates the spatial average value in the cross section. The representative point is determined in advance by measuring all points in the duct cross-section at the rated output. At partial load, the representative point is used. As an example, a measurement method in accordance with ISO 21877 is deemed appropriate. Alternatively, a full grid measurement can be carried out.

d) Unburned fuel: This should be measured according to the relevant standard applicable to the fuel and by a method agreed in advance with the purchaser and/or user.



Key

X	time		
Y	electrical output		
1	holding time	4	2nd measurement time
2	1st measurement time	5	steady-state time
3	measurement interval time	6	transient time
7	transient time the period that does not affect the tests		

NOTE If required, other load conditions can be covered under Key 5. Refer to 6.4.2.

Figure 3 — Functional or acceptance test - typical load time test profile

5.5 Functional test report

5.5.1 General

The results of the functional tests shall be reported to the purchaser and/or user in the form of a functional test report. The functional test report shall include the information listed in 5.5.2 and 5.5.3, but other information may be added as deemed necessary or for further validation of results. However, if measurement items are added, the measurement method and corresponding representative points for each measurement item shall be indicated. Examples of information that may be added include O_2, CO_2, and H_2O levels. An example of a measurement result sheet for functional test that is attached to the test report is shown in Annex B.

5.5.2 General information

The following shall be presented as common information about the measurements in the functional tests, and independent of the number of measurements to be made:

— manufacturer;

— test date, test location and person-in-charge of the test;

— nominal rated heat input of the test facility;

— weather, air temperature and relative humidity;

— measurement method and representative points for each measurement item;

— name and properties of fuel used;

— application or non-application of correction and information on correction (if applied).

All emission concentrations shall be reported in a normalized way, i.e. corrected to standard conditions for dry flue gas. A sample format for fuel properties other than fuel ammonia used in the functional tests is shown in Annex C.

NOTE Correction is a method to convert a measured performance data in the combustion test facility into the corresponding performance data for electric utility power boilers. This can include extrapolation process, numerical analysis, correction curves and manufacturer's proprietary know-how.

5.5.3 Information to be presented for each measurement

The following information shall be presented for each measurement in the functional tests:

— fuel flow rate and heat input;

— exhaust gas temperature;

— holding time, measurement time, measurement interval time, and steady-state time;

— NOx concentration;

— N_2O concentration;

— NH_3 concentration;

— unburned fuel.

In order to make clear the measurements conditions, O_2 concentration shall be reported.

6 Acceptance test

6.1 General

An acceptance test shall be conducted by the manufacturer in accordance with the equipment and test methods described in this clause; and the results shall be reported to the purchaser and/or user in the form of an acceptance test report which shall be approved by the purchaser and/or user.

6.2 Measurements for acceptance test

The concentration of the following combustion emissions shall be measured in the acceptance test:

— NOx;

— NH_3;

— N_2O;

— unburned fuel;

Furthermore, the satisfactory fulfilment of performance requirements for combustion emissions agreed upon with the purchaser and/or user for the electric utility power boilers-shall be reported in the form of an acceptance test report which shall be approved by the purchaser and/or user.

6.3 Combustion emission measurement concept

The measurement point should be between the electric utility power boiler outlet and the ancillary equipment inlet, with a measurement installation at a well-mixed location, as shown in Figure 2. Measurement should be carried out according to relevant standards as described in 6.4.3, at locations(s) where a uniform flow is expected. The measurement equipment may be permanent or temporary.

6.4 Method for acceptance test

6.4.1 Fuel

The fuel ammonia to be used for the acceptance test shall be either a gas or a liquid containing at least 99,5 % NH_3 (mass fraction) regardless of the mixing ratio. The fuel to be used for the acceptance test shall be subject to a prior written agreement between the concerned parties.

NOTE 99,5 % NH_3 is the purity that is currently commercially available.

6.4.2 Test condition

Measurements in the acceptance test shall be made at the rated electrical output, if it covers maximum emission. However, tests at other load conditions may be conducted too based on mutual agreement between the manufacturer and the purchaser and/or User. No operation of ancillary equipment that can cause interference or noise shall be performed.

6.4.3 Measurement method

After the acceptance test conditions are established and stabilized, the holding time and measurement interval time shall be secured. If there are multiple delivery test conditions, the holding time and interval time shall also be secured each time. The measurement point(s) shall be at locations where a uniform flow is expected. The measurements in the acceptance test for the measurement items in 6.2 should be performed according to the following.

a) NOx: NOx concentration should be measured automatically and continuously between the outlet of the boiler and the inlet of the ancillary equipment, with a measurement installation at a well-mixed location (see Figure 2), by establishing a representative point that indicates the spatial average value in the cross section. The representative point is determined in advance by measuring all points in the duct cross-section at the rated output. At partial load, the representative point is used. As an example, a measurement method in accordance with ISO 10849 is deemed appropriate. Furthermore, traverse (multi-point) measurement is considered as suitable; and the average value should be adopted.

b) N_2O: N_2O concentration should be measured between the outlet of the boiler and the inlet of the ancillary equipment, with a measurement installation at a well-mixed location (see Figure 2), by establishing a representative point that indicates the spatial average value in the cross section. The representative point is determined in advance by measuring all points in the duct cross-section at the rated output. At partial load, the representative point is used. As an example, a measurement method in accordance with ISO 21258 is deemed appropriate.

c) NH_3: NH_3 concentration should be measured manually in batches between the outlet of the boiler and the inlet of the ancillary equipment, with a measurement installation at a well-mixed location (see Figure 2), by establishing a representative point that indicates the spatial average value in the cross section. The representative point is determined in advance by measuring all points in the duct cross-section at the rated output. At partial load, the representative point is used. As an example, a measurement method in accordance with ISO 21877 is deemed appropriate. Furthermore, traverse (multi-point) measurement is considered as suitable; and the average value should be adopted.

d) Unburned fuel: This should be measured according to the relevant standard applicable to the fuel and by a method agreed in advance with the purchaser and/or user.

NOTE In traverse measurement, the cross section of the gas duct is divided into small areas that are practically equal and the gas analysis is done at multiple points (preferably at the centre of each small area), in order to obtain representative results.

6.5 Acceptance test report

6.5.1 General

The results of the acceptance test shall be reported to the purchaser and/or user in the form of an acceptance test report which shall be approved by the purchaser and/or user. The acceptance test report shall include the information given in 6.5.2 and 6.5.3, but other information may be added for further validation of results. However, if measurement items are added, the method of measurement and representative points for each measurement item shall be indicated. Examples of information that may be added include O_2, CO_2, H_2O, and SO_2. An example of a format of the measurement result sheet for acceptance test that is attached to the test report is shown in Annex D.

Central control room data such as date and time, generator electrical output, steam conditions, fuel consumption, gas temperature, thermal input, exhaust gas composition, may be attached as an operational record during the acceptance test.

6.5.2 General information

The following shall be presented as common information about the measurements in the acceptance test, and independent of the number of measurements to be made:

— manufacturer;

— date, place and person in charge of the test;

— weather, air temperature, and relative humidity;

— method of measurement and representative points for each measurement item;

— name and properties of the fuel used.

Examples of fuel properties for solid, liquid and gaseous fuels other than fuel ammonia used in the tests are shown in Annex C.

6.5.3 Information to be presented for each measurement

The following information shall be presented for each measurement in the acceptance test:

— generator output;

— fuel thermal input;

— exhaust gas temperature;

— holding time, measurement time, measurement interval time, and steady-state time;

— NOx concentration;

— N_2O concentration;

— NH_3 concentration;

— unburned fuel.

In order to make clear the measurements conditions, O_2 concentration shall be reported.

Annex A
(informative)

General concept of purchaser and/or user's performance requirements for ammonia-fired boilers

A.1 General

This annex provides, by way of reference, technical information on the approach to be taken in formulating the purchaser and/or user's performance requirements as indicated in 4.1 for power generation boilers that use fuel ammonia.

A.2 Key points to take into consideration when setting performance requirements

For ammonia-fired boilers, the following three measurement items specified in 5.2 and 6.2 are performance requirements that should be considered in particular, in view of the fact that these are power generation boilers that use ammonia:

— NOx;

— NH_3;

— N_2O.

On the other hand, since the knowledge available at present is limited, the criteria for setting the performance requirements can change with future research and development. Therefore, the purchaser and/or user should refer to the latest technical literature and other relevant materials when setting performance requirements.

A.3 Key points to take into consideration for each measurement item

A.3.1 NOx

In terms of environmental performance, the lower the NOx emissions, the better. Currently, it is expected that NOx emissions can be reduced to the same level as those of non-ammonia alone, for up to 20 % fuel ammonia firing.[9] For NOx, the performance requirement should be set by referring to the latest technical literature and other relevant materials, depending on the fuel ammonia mixing ratio.

A.3.2 NH_3

NH_3 fed as fuel should be completely combusted in the combustion chamber. Therefore, it should be a performance requirement that NH_3 be almost, if not fully, undetectable. However, the performance requirement should be set by referring to the latest technical literature and reference materials, depending on the fuel ammonia mixing ratio. In case of a selective catalytic reduction being installed at the plant, the unburnt fuel ammonia can be reduced as well.

A.3.3 N_2O

N_2O is one of the main GHG and is an important environmental measurement substance to evaluate or validate the environmental performance of ammonia-fired boilers. As with NOx, the required performance should be set according to the fuel ammonia mixing ratio, with reference to the latest technical literature and other relevant materials[9].

Annex B
(informative)

Sample of functional test - measurement results format

This annex provides a sample of the “functional test – measurement results format” for ammonia-fired boilers as shown in Table B.1. The units shown are for reference purposes only.

Table B.1 — Sample of measurement results format of functional test

Manufacturer	Solid fuel name	Test date D/M/Y
Model, serial number	Solid fuel heating value (higher/lower) MJ/kg	Test location
Fuel ammonia purity %	Liquid fuel name	Test equipment nominal rated heat input MWth
Fuel ammonia heating value (higher/lower) MJ/kg	Liquid fuel heating value (higher/lower) MJ/kg	Person in charge of testing
Fuel ammonia mixing ratio (heat input ratio) %	Gaseous fuel name	Weather Air temperature °C
Definition of normal state	Gaseous fuel heating value (higher/lower) MJ/Nm^3	Relative humidity %

Measurement No.	Measurement time	Fuel flowrate				Heat input (MWth)	Exhaust gas temp. (°C)	Exhaust gas composition							
		Fuel ammonia (kg/h)	Solid fuel (kg/h)	Liquid fuel (kg/h)	Gaseous fuel (kg/h)			NOx (ppm) (continuous)	N_2O (ppm) (batch)	N_2O (ppm) (continuous)	NH_3 (ppm) (batch)	NH_3 (ppm) (continuous)	O_2 (dry%)	H_2O (wet%)	CO_2 (wet%)
Average value															

Annex C
(informative)

Sample fuel properties format

This annex provides a sample format of fuel properties to be included in the functional test report for ammonia-fired boilers as shown in Table C.1, Table C.2 and Table C.3. The units shown are for reference purposes only.

Table C.1 — Sample fuel properties format of solid fuel

Analysis item		Unit	Analytical value	Remarks
Brand/Description		—		
Proximate analysis (air dried basis)	Higher heating value	MJ/kg		
	Lower heating value	MJ/kg		
	Fixed carbon	%		
	Volatile matter	%		
	Ash	%		
	Inherent moisture	%		
	Total	%	100	
	Surface moisture	%		
	Total sulfur	%		
Ultimate analysis (dry)	C	%		
	H	%		
	O	%		
	N	%		
	S	%		
	Ash	%		
	Total	%	100	
Ash fusion temp. (hemispherical)	Reducing	°C		
	Oxidizing	°C		
Ash composition	SiO_2	%		
	Al_2O_3	%		
	Fe_2O_3	%		
	TiO_2	%		
	P_2O_5	%		
	CaO	%		
	MgO	%		
	K_2O	%		
	Na_2O	%		
	SO_3	%		

Table C.2 — Sample fuel properties format of liquid fuel

Analysis item		Unit	Analytical value	Remarks
Type		—		
Specific gravity		—		
Viscosity (@50 °C)		mm^2/s		
Pour point		°C		
Residual carbon content		%[a]		
Higher heating value		MJ/kg		
Lower heating value		MJ/kg		
Ultimate analysis	C	%[a]		
	H	%[a]		
	O	%[a]		
	S	%[a]		
	N	%[a]		
	Ash	%[a]		
	Moisture	%[a]		

[a] Mass fraction.

Table C.3 — Sample fuel properties format of gaseous fuel

Analysis item		Unit	Analytical value	Remarks
Type		—		
Specific gravity		Kg/Nm^3		
Higher heating value		MJ/Nm^3		
Lower heating value		MJ/Nm^3		
Gas composition	Methane	%[a]		CH_4
	Ethane	%[a]		C_2H_6
	Propane	%[a]		C_3H_8
	Butane	%[a]		C_4H_{10}
	Isobutane	%[a]		C_4H_{10}
	Pentane	%[a]		C_5H_{12}
	Hexane	%[a]		C_6H_{14}
	Ethylene	%[a]		C_2H_4
	Propylene	%[a]		C_3H_6
	CO	%[a]		
	H_2S	%[a]		
	H_2	%[a]		

[a] Volume fraction.