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Gas turbine exhaust systems with or without waste heat recovery

Systèmes d'échappement des turbines à gaz avec ou sans récupération de la chaleur résiduelle

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 192, *Gas turbines*.

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

This document has been developed in response to the international market need for a specification relating to the exhaust and heat recovery systems for gas turbines. Purchasers and suppliers will benefit from a standard against which equipment can be purchased, designed and constructed - especially given the challenging nature of the turbulent exhaust gas flow and associated complexity of mechanical design. Equipment is frequently installed in remote and challenging locations both onshore and offshore where maintenance and repair can be prohibitively expensive.

A waste heat recovery unit recovers thermal energy from the waste heat available in gas turbine exhaust gases, exchanged into various heat transfer media such as water, water/glycol mixtures, thermal oils and hydrocarbon gases.

The application of heat recovery devices to gas turbines results in significant thermal efficiency gains and resultant environmental benefit from reduction in CO_2 emissions. Gas turbine exhaust is one of many sources of waste heat energy and can be classed as medium grade within a typical temperature range between 400 °C and 600 °C suitable for Rankine cycle applications.

Gas turbine exhaust systems with or without waste heat recovery

1 Scope

This document specifies requirements and gives recommendations for the design, materials of construction, modelling, controlling, fabrication, inspection, testing, installation, start-up and operation of industrial gas turbine (GT) exhaust systems with or without waste heat recovery unit (WHRU). Gas turbines can be on-shore or off-shore for such sectors as oil and gas, chemical and process industries, utilities, or other intensive energy users.

For this document, the exhaust system means all items in the turbine exhaust gas stream between the GT exhaust gas collector outlet flange and the termination/s to the atmosphere.

The following items are not covered by this document:

— heat recovery steam generator equipment (HRSG);

— supplementary fired systems;

— auxiliary fired systems;

— exhaust gas collector (also known as exhaust plenum);

— fire detection and extinguishing systems;

— emissions controls equipment intended to modify the gaseous composition of the exhaust gas;

— WHRUs that are of the firetube type, where the turbine exhaust gas (TEG) passes through the tubes.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3744, *Acoustics — Determination of sound power levels and sound energy levels of noise sources using sound pressure — Engineering methods for an essentially free field over a reflecting plane*

ISO 9614, *Acoustics — Determination of sound power levels of noise sources using sound intensity*

ISO 10494, *Turbines and turbine sets — Measurement of emitted airborne noise — Engineering/survey method*

ISO 10474, *Steel and steel products — Inspection documents*

ISO 12241, *Thermal insulation for building equipment and industrial installations — Calculation rules*

ISO 13704, *Petroleum, petrochemical and natural gas industries — Calculation of heater-tube thickness in petroleum refineries*

ISO 13705:2012, *Petroleum, petrochemical and natural gas industries — Fired heaters for general refinery service*

ISO 13916, *Welding — Measurement of preheating temperature, interpass temperature and preheat maintenance temperature*

ISO 14122, *Safety of machinery — Permanent means of access to machinery*

ISO 14555, *Welding — Arc stud welding of metallic materials*

ISO 15612, *Specification and qualification of welding procedures for metallic materials — Qualification by adoption of a standard welding procedure specification*

ISO 15613, *Specification and qualification of welding procedures for metallic materials — Qualification based on pre-production welding test*

ISO 15614-1, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys*

ISO 19902, *Petroleum and natural gas industries — Fixed steel offshore structures*

ASME B16.9, *Wrought steel butt-welding short radius elbows and returns*

ASME B31.3, *Petroleum Refinery Piping*

ASTM C680-10, *Standard Practice for Estimate of the Heat Gain or Loss and the Surface Temperatures of Insulated Flat, Cylindrical, and Spherical Systems by Use of Computer Programs*

EN 287-1, *Qualification test of welders — Fusion welding — Steels*

EN 1011-2, *Welding — Recommendations for welding of metallic materials — Part 2: Arc Welding of Ferritic Steels*

EN 1991-1-4, *Eurocode 1: Actions on structures — Part 1-4: General actions — Wind actions*

EN 10025-2, *Hot rolled products of structural steels — Technical delivery conditions for non-alloy structural steels*

EN 10025-3, *Hot rolled products of structural steels — Technical delivery conditions for normalized/normalized rolled weldable fine grain structural steels*

EN 10253-2, *Butt-welding pipe fittings. Non alloy and ferritic alloy steels with specific inspection requirements*

EN 13445-3:2014, *Unfired pressure vessels — Part 3: Design*

EN 13480, *Metallic Industrial piping*

EN 15614, *Specification and qualification of welding procedures for metallic materials*

3 Terms and definitions

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

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

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

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

3.1
analogue control signal
control or digital signal that represents a continuous range of values

EXAMPLE A traditional 4-20 mA current loop.

3.2
commissioning
action whereby dynamic checks and tests where the GT is running, the exhaust system is subject to TEG flow and the WHRU is filled with circulating HTMs, progressively loaded with control systems and functioning

3.3
data sheet
formal document containing process and/or mechanical data

3.4
insulation
material applied to either the inside or outside of the exhaust system component casings (e.g. WHRU, ducting, stacks, dampers) in order to reduce the casing material or outer cladding temperature, respectively

3.5
pre-commissioning
static checks and tests where the exhaust system is cold and the WHRU is not filled with HTM and the controls are energized

3.6
purchaser
party that enters into contract with the *supplier* (3.8) for the supply of the exhaust system

Note 1 to entry: The purchaser is the party who specifies the technical requirements. The purchaser can also instruct a *contractor* (3.7), an agent or consultant, authorized to act for, and on his behalf. The purchaser can in some cases also be the GT supplier.

3.7
contractor
party that carries out all or part of the design, engineering, procurement, construction, *commissioning* (3.2) or management of a project or operation of a facility

Note 1 to entry: The *purchaser* (3.6) can choose to undertake all or part of the duties of the contractor

3.8
supplier
party that manufactures or supplies equipment and services to perform the duties specified by the *purchaser* (3.6)

3.9
WHRU tube bundle
hairpin tube bundle arrangement contained within a rectangular casing, or a nested helical coiled tube arrangement contained within a cylindrical casing

4 Abbreviated terms

ALS	Absolute limit state
CFD	Computational fluid dynamics
CHT	Conjugate heat transfer
CSCC	Chloride stress corrosion cracking
COTS	Commercial off the shelf
DES	Detached eddy simulation

DFF	Design fatigue factor
DLE	Dry low emission
DNS	Direct numerical simulation
FAT	Factory acceptance test
FEM	Finite element method
FPSO	Floating production storage and offloading
FLS	Fatigue limit state
FSI	Fluid structure interaction
GT	Gas turbine
HART	Highway addressable remote transducer
HCF	High cycle fatigue
HTM	Heat transfer medium
ITP	Inspection and test plan
LES	Large eddy simulation
LCF	Low cycle fatigue
MLD	Multi louvre damper
NDT	Non-destructive test
P&ID	Piping and instrument diagram
PMI	Positive material identification
PQR	Procedure qualification record
PT	Penetrant test
RANS	Reynolds averaged Navier-Stokes CFD modelling (generally referring to modelling steady flow behaviour)
RFQ	Request for quotation
SDRL	Supplier document requirement list
TEG	Turbine exhaust gas
ULS	Ultimate limit state
URANS	Unsteady Reynolds averaged Navier-Stokes CFD modelling
WHRU	Waste heat recovery unit
WPQ	Welding procedure qualification
WPS	Welding procedure specification

5 Proposals

5.1 Purchaser's responsibilities

The purchaser's enquiry should include data sheets, checklist and other applicable information outlined in this document. This information should include any special requirements or exceptions to this document (see Annex C).

The purchaser is responsible for the correct process specification to enable the supplier to carry out the exhaust system design and manufacture.

The purchaser is responsible to clearly state the supplier's scope of supply.

The purchaser's enquiry should specify the number of copies of drawings, data sheets, specifications, data reports, operating manuals, installation instructions, spare parts lists and other data to be provided by the supplier.

5.2 Supplier's responsibilities

The supplier's proposal should include:

a) data sheets for each exhaust system and the associated equipment;

b) an outline drawing showing as a minimum, layout and clearances, arrangement of tube bundles, platforms, ducting, damper systems and stack;

c) a definition of the extent of shop assembly, including the number, size and weight of prefabricated parts and the number of field welds;

d) a detailed description of any exceptions to the specified requirements including this document;

e) a completed noise data sheet if specified by the purchaser;

f) a time schedule for submission of all required drawings, data and documents;

g) a program for scheduling the work after receipt of an order; this should include a specified period of time for the purchaser to review and return drawings, procurement of materials, manufacture and the required date of supply;

h) a list of utilities and quantities required;

i) if specified by the purchaser, a list of proposed sub-suppliers for major components and items, which can include steel plate, insulation materials, expansion joints, tubes and extended surfaces on tubes, fittings, tube bundle fabrication, dampers, castings, steel fabrication, ladders and platforms and other auxiliary equipment.

The supplier shall identify all parts and components with a shorter estimated lifetime than that specified for the complete system or which will need maintenance and/or removal for service. Expansion joints, damper, actuators and seals are examples of such components.

6 Basic exhaust system design

6.1 General

GT exhaust systems can be with or without a WHRU and damper system which recovers heat from the exhaust of a GT and exchanges this heat into HTM to supplement the thermal requirements of another process. The WHRU enhances the thermal efficiency of the cycle with minimal impact on the operation of the GT itself.

6.2 Exhaust system configuration

Each exhaust system should normally be connected to its own GT. In the event that more than one GT is connected to an exhaust system, then special considerations would apply which are not covered in detail in this document.

6.3 Service life

Unless otherwise stated by the purchaser, the design, selection of equipment and materials and corrosion protection shall be based on a design lifetime of 20 years with 30 starts/stops from cold to full load per year. The supplier should supply the service life and minimum uninterrupted operation interval based on each specific application. The maintenance procedure necessary to achieve these intervals should also be supplied.

NOTE For highly cyclic GT applications, e.g. in single cycle mode, where the start/stop cycles are significantly more frequent, the risk of fatigue on various parts of the WHRU increases.

6.4 Supply responsibility

Supply responsibility for the exhaust system should be either with the GT supplier or contracted directly between the purchaser and the exhaust system supplier.

6.5 GT characteristic data

If the exhaust system is purchased under the GT supplier responsibility then the GT supplier is responsible to provide the required dimensional, acoustic, thermal, flow characteristics (steady state and transient) and mechanical information to the exhaust system supplier as specified in this document.

In the event that the purchaser contracts directly with the exhaust system supplier then it becomes the purchaser's responsibility to obtain this data from the GT supplier and pass it on the exhaust system supplier.

6.6 Required operating envelope

The purchaser is responsible to define the equipment's required operating envelope which should be shown on the data sheets including any dry run requirements as defined in 9.3.2.

The supplier is responsible for ensuring that all items of equipment and components provided are designed for the specified operating conditions.

The supplier shall ensure that the equipment takes account of all potential applied loads (typically seismic, transportation, wind loads, etc.).

6.7 Equipment specification

The exhaust system should be proven in practice, robust, reliable, safe, operable and maintainable.

The exhaust system should be based on the least number of factory-built modules consistent with transport and site erection dimensional and weight restrictions.

The exhaust system shall be designed and constructed to meet all operational cases specified in the RFQ.

6.8 WHRU equipment specification

Materials of construction for the tube bundle pressure parts shall be selected from internationally recognized material codes. The supplier's data sheets shall clearly state the location(s) of each material.

The WHRU shall be designed to provide the required performance with no negative tolerance. The design shall consider the selected fouling factor and required degree of over-surface to ensure that these requirements are met.

NOTE The HTM can typically be the following:

(i) a water/glycol solution;

(ii) hot oil/thermal oil;

(iii) water;

(iv) hydrocarbons, liquid or gaseous.

In the final selection of the HTM, due consideration should be given to operating temperatures and pressures, the degradation limits, surface tension, toxicity, flammability and corrosiveness of the HTM.

6.9 Operating conditions

Each component of the exhaust system (e.g. WHRU tube bundle and supports, casings and linings, ductwork, dampers, etc.) shall be capable of withstanding the most severe temperature specified plus a margin as defined in Clause 8.

6.10 Operating environment

The equipment, including all auxiliaries, shall be designed for operation under the environmental conditions specified by the purchaser. These conditions should include whether the installation is indoors (heated or unheated) or outdoors, maximum and minimum temperatures, unusual humidity, and dusty or corrosive conditions, wind, earthquake and/or sea motions during operation and transport. The unit and its auxiliaries shall be designed for shipment and installation under the specified conditions.

If sub-zero ambient temperatures are specified by the purchaser, then appropriate materials and test procedures should be applied.

6.11 Equipment arrangement

The arrangement of the equipment, including piping and auxiliaries, should be developed jointly by the purchaser and the supplier. It is the purchaser's responsibility to identify dimensional limitations for the location of the exhaust system including space required for tube bundle and/or tube removal as well as any handling weight limitations that apply. The arrangement should be submitted by the supplier to the purchaser for review and agreement during the proposal phase.

The purchaser is responsible for specifying any weight limitations (e.g. maximum total equipment weight, maximum lifted weight). If no such limitations exist, at least the total equipment weight with applicable margin (e.g. ±10 %) should be included in the supplier's proposal.

6.12 Provision for future addition of WHRU

Where specified by the purchaser, the exhaust system shall include provision for future installation of a WHRU. This should include the bolted panel sized for the full exhaust flow to which a future WHRU can be connected. It should also include bolted duct section which can be replaced with a future damper or diverted system.

6.13 Electrical equipment

Motors, electrical components, and electrical installations shall be certified for the area classification specified (class, group, and division or zone).

6.14 Field assembly and disassembly

The supplier shall state in the proposal the proposed method for the disassembly required for repair or replacement of exhaust system parts such as expansion joints, WHRU, dampers or silencers. While tube failures are rare, if specified by the purchaser, the design shall include provision for tube bundle pressure part repair or replacement.

6.15 Special tools and fixtures

If special tools and fixtures are required to disassemble, assemble or maintain the unit, they shall be included in the supplier's proposal and furnished as part of the initial supply of the equipment. For multi-unit installations, the requirements for quantities of special tools and fixtures should be agreed between the purchaser and the supplier.

6.16 Spare parts

Spare parts supplied with the main equipment delivery shall be identical to the fitted parts.

6.17 Deviations

All proposed deviations of the supplier's equipment from this document shall be listed by the supplier with the bid.

7 Documentation

7.1 General

The supplier should provide all drawings, design details, calculations, and analysis, operation and maintenance manuals, and other information necessary for the design assessment, erection, operation and maintenance of the exhaust system installation. All information should be clear and not open to misinterpretation and shall apply specifically to the installation supplied.

The purchaser should specify which documentation is required to be provided in a local language.

The purchaser should specify the format and number of copies of documentation required from the supplier.

Unless otherwise specified and agreed by the purchaser all documentation should be submitted in electronic format.

All calculations and documentation shall be prepared using the agreed unit system for the project.

7.2 Data sheets

Data sheets should be used for the exchange of specification related information between the purchaser and the supplier. The purchaser is responsible for providing the GT data and corresponding WHRU thermal loads for the required duty envelope. The supplier shall provide completed data sheets with confirmation that performance requirements are met.

The recommended data sheet format for WHRUs is available for download using the link given in Annex E.

7.3 Supplier document requirements

The purchaser should provide a SDRL for the exhaust system.

The supplier shall provide the documents listed in Table 1 for review unless otherwise specified by the purchaser.

The purchaser should specify which documents are subject to his approval.

Table 1 — Documentation to be provided by the supplier and reviewed by the purchaser

Document	Remark
Calculations demonstrating compliance with specification requirements, including any pressure part and structural design codes	
Data sheets	Detailing process design and performance data at all specified operating cases. Mechanical, materials and construction data Key dimensions and weight
Suppliers manufacturing data report	
FAT procedure	
Site performance acceptance test procedure	
General arrangement drawings	Showing locations of all interfaces and major dimensions
Hazardous area and ingress protection certification for all electrical components.	
Welding and NDT data, including — WPS and PQR — WPQ — Weld map — ITP — NDT procedures — NDT personnel qualifications — Procedure for storage and handling of filler metals	
Inspection certificates for all metallic materials of construction.	Material certificates in accordance with ISO 10474[a], type 3.1 for all pressure parts and type 2 for materials of exhaust gas ducts/casings. The certificates shall satisfy the applicable code requirements.
Installation, operating and maintenance instructions	
Spare parts list	Commissioning and operational and strategic spare parts lists
Pre-commissioning and commissioning instructions	
Pressure and capacity test certificates for any pressure relief valves	
Pressure test certificates for any fabricated pressure parts	
Quality plan	
Fan and motor curves and data sheets for all fans.	To include: — sound power levels and sound pressure levels — test reports
Sound power levels and sound pressure levels of the equipment.	
P&IDs and controls description including alarm and trip points and cause and effect.	In accordance with appropriate ISO code and shall be complete, comprehensive and consistent

[a] Reference can also be made to EN 10204 with regards to material certificates.