

DEP SPECIFICATION

COMBUSTION GAS TURBINES - SELECTION, DESIGN, ENGINEERING, TESTING AND INSTALLATION

DEP 31.29.70.11-Gen.

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DESIGN AND ENGINEERING PRACTICE

DEM1



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1. INTRODUCTION

1.1 SCOPE

This DEP supplements API STD 616 by providing supporting information for the specification and guidance on its use.

It is intended to be used by owners and Engineering Procurement Contractors and not forwarded to Manufacturers/Suppliers as a design specification.

This DEP contains mandatory requirements to mitigate process safety risks in accordance with Design Engineering Manual (DEM) 1 – Application of Technical Standards.

This is a revision of the DEP of the same number dated September 2011; see (1.5) regarding the changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorisation to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in facilities related to oil refineries, chemical plants, gas plants and, where applicable, in exploration and production facilities. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process shall be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regards to the safety, environmental, economic and legal aspects. In all cases, the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

In API STD 616, the term **Vendor** is used. In this DEP, the term **Vendor** shall be understood to mean the Manufacturer/Supplier.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The **Purchaser** is the party which buys the turbine and its auxiliaries for its own use or as agent for the owner. The Purchaser may be either the Principal or the Contractor.

In API STD 616, the term **Purchaser** is used. In this DEP, the term **Purchaser** shall be understood to mean the Principal.

The word **shall** indicates a requirement.

The capitalized term **SHALL [PS]** indicates a process safety requirement.

The word **should** indicates a recommendation.

The word **may** indicates a permitted option.

1.3.2 Specific definitions

Term	Definition
Availability	The availability of a gas turbine is defined as the sum of the service hours (i.e., the period in which the unit is producing useful energy) divided by the sum of service hours plus total outage hours, and is expressed as a percentage.
Heat rate (kJ/kWh)	A measure of engine efficiency and is equal to 3600 divided by efficiency (when efficiency is given in decimal form).
Industrial type single shaft gas turbine	Arrangement in which the turbine shaft that is connected to the driven equipment is also connected to the gas turbine air compressor shaft
Industrial type two-shaft gas turbine	Arrangement in which the turbine shaft that is connected to the driven equipment is not connected to the gas turbine air compressor shaft.
ISO rating	The ISO rating of a gas turbine is its rating at 15 °C (59 °F) ambient temperature, 1013.25 mbar atmospheric pressure and 60 % relative humidity, with zero inlet and exhaust pressure losses.
Prototype	A design of gas turbine or component whose leading engine has not yet achieved 98 % reliability over 25,000 fired hours, or where the total population of identical gas turbines has achieved less than 100,000 fired hours. In this definition, it is the gas turbine itself that is considered and not the entire package unit with auxiliaries.
Proven Equipment	Equipment of which at least three units of similar type, size and specific loading have together accumulated a minimum of 24,000 hours of comparable satisfactory service.
Reliability	The reliability of a gas turbine is defined as the sum of the service hours (i.e., the period in which the unit is producing useful energy) divided by the sum of service hours plus forced outage hours, and is expressed as a percentage.
Site rated power	The shaft power developed by the gas turbine when it is operated in a new and clean condition, including clean air filters and air compressor at site rated firing temperature, rated speed and site conditions of air inlet temperature, air inlet pressure, exhaust back pressure and specified fuel composition. The site rated power is regarded as the guaranteed power capability of the gas turbine and is the power available at the gas turbine load coupling after extracting parasitic losses such as fuel and lubricant pumps, internal speed changers.

Term	Definition
SPEP	Shell Pre-Engineered Product specification is a technical pre-agreed solution between Shell Corporate and the specific Manufacturer. SPEP covers agreed: • Technical configurations and options • Deviations to Shell Requirements • Detailed design reviews; e.g.: HAZOP, IPF
Vital, Essential and Non-essential service	For definitions and explanation of these services see Appendix 1.

1.3.3 Abbreviations

Term	Definition
CEMS	Continuous Emission Monitoring System
DCS	Distributed control system
DLE	Dry Low Emissions
ESD	Emergency Shutdown
FAR	Field Auxiliary Room
GRP	Glass-Reinforced Plastic
HAZOP	Hazards and Operability Study
MLO	Mineral lube oil
PCD	Process Control Domain
SIS	Safety Instrumented System
SLO	Synthetic lube oil
WLE	Wet low emission
WHRU	waste heat recovery unit

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section or clause number is shown in brackets (). Other documents referenced by this DEP are listed in (17).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a revision of the DEP of the same number dated September 2011. The following are the main, non-editorial changes:

This is a complete rewrite of this DEP, to incorporate minimum evaluation criteria extracted from the archived DEP 31.29.70.31-Gen.

The updates apply the following approach:

- Equipment design, manufacturing and testing requirements have been moved to the applicable DEP Specification
- Superfluous text has been removed
- References to DEPs without added value have been removed
- Minimum Shell requirements have been applied to stay close to industry solutions.

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be submitted to the Administrator using one of the following options:

Shell DEPs Online (Users with access to Shell DEPs Online)	Enter the Shell DEPs Online system at https://www.shelldeps.com Select a DEP and then go to the details screen for that DEP. Click on the "Give feedback" link, fill in the online form and submit.
DEP Feedback System (Users with access to Shell Wide Web)	Enter comments directly in the DEP Feedback System which is accessible from the Technical Standards Portal http://swwww.shell.com/standards . Select "Submit DEP Feedback", fill in the online form and submit.
DEP Standard Form (other users)	Use DEP Standard Form 00.00.05.80-Gen. to record feedback and email the form to the Administrator at standards@shell.com .

Feedback that has been registered in the DEP Feedback System by using one of the above options will be reviewed by the DEP Custodian for potential improvements to the DEP.

1.7 DUAL UNITS

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

1.8 NON NORMATIVE TEXT (COMMENTARY)

Text shown in italic style in this DEP indicates text that is non-normative and is provided as explanation or background information only.

Non-normative text is normally indented slightly to the right of the relevant DEP clause.

2. GENERAL REQUIREMENTS

2.1 GENERAL

This standard covers the minimum requirements for:

- *Open, simple and regenerative cycle combustion gas turbine units for mechanical drives or generator drives.*
- *Industrial gas turbines, modular or aeroderivative gas turbines.*
- *Land based, offshore and mobile trailer mounted gas turbine units.*

The definitions in (1.3.2) are independent of the requirements for a service life of 20 years and for at least three years of uninterrupted operation, as specified by API STD 616.

2.2 ALTERNATIVE DESIGNS

1. Alternative designs to those detailed in this DEP shall be subject to approval by the Principal.

2.3 CONFLICTS

1. If there is conflict between documents relating to the enquiry or purchase order, the following hierarchy of documents shall apply:
 - a. First level: Local rules and regulations;
 - b. Second level: Purchase order and variations thereto;
 - c. Third level: Data/requisition sheets and project drawings;
 - d. Fourth level: SPEP (if applicable);
 - e. Fifth level: This DEP;
 - f. Sixth level: API STD 616.
2. Any apparent conflict between the requirements of this DEP and any other applicable document in the purchase order shall be notified to the Principal for clarification purposes.

2.4 SELECTION AND EVALUATION

2.4.1 Gas turbines

1. The selection of gas turbines and the technical evaluation of bids from gas turbine Manufacturer/Suppliers shall be based on the requirements of this DEP together with API 616.

2.4.2 Air inlet systems

1. The selection of ventilation and combustion air intake systems and the technical evaluation of bids air inlet system Manufacturer/Suppliers shall be based on the requirements of this DEP together with API 616 and the requirements specified in (Appendix 2).

2.4.3 Exhaust systems

1. The selection of exhaust systems and the technical evaluation of bids from exhaust systems Manufacturer/Suppliers shall be based on the requirements of this DEP together with API 616.

2.5 RANGE AND VARIETY OF GAS TURBINES

1. The level of spares should be minimised by rationalising the variety of makes and types of gas turbines, the associated drives and auxiliary equipment on a project.

2. The rationalisation of variety and minimisation of spares should not prevent selection of the most suitable gas turbine for the specified operating conditions and not increase the total cost of ownership (TCO).

2.6 PROTOTYPE GAS TURBINES

1. Selected equipment shall be within the range of the Manufacturer/Supplier's proven experience and not involve the use of prototype designs or components, except where pre-approved by the Principal.
 - a. The Manufacturer/Supplier's experience with hot parts and the proposed firing temperature shall be assessed and documented.
 - b. Any changes to the axial compressor design including reduced design margins shall be reviewed against operational experience.

2.7 OPERATING REQUIREMENTS

1. All operating requirements that the gas turbines may need to fulfil shall be specified in the data requisition sheet, including the following:
 - a. Off-design conditions, which might occur during start-up and shutdown procedures associated with the particular applications of the gas turbine.
 - b. Parallel operation, if required.
2. The waste heat recovery unit shall be designed for the maximum gas turbine exhaust temperature under the worst conditions: maximum ambient, peak firing, turn down.

The exhaust mass flow and temperature under part-load conditions are important considerations for gas turbines in co-generation and combined cycle applications, especially if exhaust heat is to be used for steam generation without supplementary firing of the boiler.
3. The Manufacturer/Supplier shall provide performance data corresponding to the minimum continuous load at which the gas turbine can operate, including the minimum load at which guaranteed gaseous emissions can be achieved.

2.8 SPARES INVENTORY

1. A spares inventory comprising either a recommended range of individual components or a complete gas generator and/or rotors, or a combination of both, shall be dictated by the required plant availability and maintenance strategy.

In some cases, holding a complete spare gas generator can be more economical in the longer term than holding individual components.

Gas generators or spare rotors can be shared with other users or the Manufacturer/Supplier stocks the parts and guarantees immediate availability.

If service centres are locally available and are prepared to maintain an adequate level of spares in stock, a smaller spares inventory might be required.
2. Spare gas generators and/or rotors shall be stored per Vendor standard instructions, in nitrogen-pressurised metal containers.
 - a. The pressurised containers shall be supplied as original equipment by the gas turbine Manufacturer/Suppliers.
3. Procurement of additional operational spares should be considered, in consultation with the Principal, for gas turbines located in regions, locations or countries, where quick access to parts and services by Manufacturer/Suppliers can be challenging.

2.9 COMPLETE UNIT RESPONSIBILITY

1. The complete unit (i.e., gas turbine, driven equipment and all auxiliary equipment, including lubrication, control and instrumentation systems) shall be ordered from one responsible party.
 - a. For a mechanical drive configuration, the order shall be made to the driven equipment Manufacturer/Supplier.
 - b. Where agreed with the Principal, the driver Manufacturer/Supplier may be responsible for the total train.
 - c. For an electrical generator drive configuration, a complete package may be ordered from the gas turbine Manufacturer/Supplier, or from a packager or its associates, who have been approved for this purpose by the Principal.

2.10 API 616 BULLET ITEMS

A bullet (•) in the margin against certain clauses (paragraphs) in API 616 indicates that a decision by the Principal is required. This DEP gives guidance to select bullet items.

1. The final selection of bullet items in API 616 used for guidance shall be agreed between Contractor and Principal.
 - a. The selection of bullet items for guidance in API 616 shall be indicated on the relevant data/requisition sheet when provisions are made for them.
 - b. If provisions are not made for selected bullet items from API 616, they shall be indicated on the data/requisition sheet(s) under the heading 'Additional Requirements' or stated in the Purchase Order.

3. TYPE SELECTION

3.1 GENERAL

There are two types of combustion gas turbines:

- Industrial combustion gas turbines, and
- Aero-derivative gas turbines.

1. The choice for an industrial gas turbine or an aero-derivative gas turbine shall be based on the total cost of ownership evaluation.
 - a. An aero-derivative gas turbine should not be excluded if allowable mass and available space is limited, such as in offshore or oil field applications.
2. The enquiry requisition data sheet shall include on-site restrictions for construction that could impact the choice of packaged, modularised or trailer mounted units.

Fully packaged, modular or trailer mounted gas turbine and control units require special consideration for use in challenging locations, where 'on-site' construction activity needs to be minimised.

3. The reliability and availability of the specific gas turbine under consideration should be key criteria for determining the plant on-stream time and the total cost of ownership.
4. If the gas turbine fuel could be a crude oil, residual fuel oil, then industrial gas turbines shall be specified.
5. For generator drives, a single-shaft industrial gas turbine should be chosen, since the greater inertia inherent in this type gives improved grid stability and it is simpler and more easily maintained.
6. If based on TCoO evaluation, an aero-derivative gas turbine is the best choice or a multi shaft design the only available design, the grid stability shall be analysed against the gas turbine control response capabilities.

7. Recuperative (regenerative) gas turbines should only be considered if the selected recuperative heat exchanger has proven reliable in similar applications.
8. Waste heat recovery from the hot gas for steam generation or process heating should be considered.
 - a. The design shall ensure that failure of the waste heat recovery unit or its control system does not adversely affect process or power reliability and availability.
9. Apart from the ambient condition derating, the site rating should be adequate to cover losses due to those aspects listed in Table 1.

Having established the site rating for the gas turbine, the ISO rating of the gas turbine can be calculated to serve as a guide for comparing the available makes and models of the gas turbine type suitable for the application.

10. All derating factors shall be verified with the Manufacturer/Suppliers during the proposal phase and confirmed in the purchase requisition.
11. ISO ratings of the makes and models shall be clearly correlated with the load envisaged.

Manufacturers/Suppliers tend to indicate different ratings for base load, peak load, reserve peak load etc., in combination with gas or liquid firing, sometimes also with a reduced lifetime for gas turbine blading and components in the hot gas path.

12. A flat rating, where the power output offered is independent of ambient temperature shall not be accepted.

Flat rating offered by some Manufacturer/Suppliers assumes a constant power output irrespective of ambient temperature, compensating for the increased firing temperatures at high ambient by reduced firing temperatures at low ambient. The life of a gas turbine is determined by the creep life of critical hot parts which decreases rapidly with cumulative operating hours at the highest firing temperature.

Table 1 Typical derating factors (DF)

Description of derating factors (DF)	% loss on power	Derating factor
Unrecoverable losses (ageing / wear & tear / fouling), DF1 ¹⁾		
• With E12 filtration	1%	0.99
• With < E12 filtration (e.g. F8/F9/E10)	4%	0.96
Inlet system loss (1.5% loss / 100 mm wc), DF2 ²⁾		
• Inlet air filters, silencer, IBH, air duct (nominal 120 mm wc)	1.8%	0.982
Outlet system loss (0.5% loss / 100 mm wc), DF3 ²⁾		
• Exhaust system (including exhaust duct, silencer, stack) (nominal 100 mm wc loss)	0.50%	0.995
• Exhaust system + Single through steam generator / hot oil (nominal 150 mm wc loss total)	0.75%	0.9925
• Exhaust system + Normal steam boiler/WHRU (nominal 300 mm wc loss total)	1.50%	0.985
• COR & SCR (add 100 mm wc loss, if applicable)	add 0.5%	subtract 0.005
Main gearbox (if applicable) DF4	2%	0.98
API 617 power margin for process compressors (as applicable), DF5 ³⁾		
• GT below 25MW ISO power	--	1.04
• GT above 25MW ISO power, single duty on one shaft	--	1.02
• GT above 25MW ISO power, two duties on one shaft	--	1.03
$\text{Gas Turbine derated power} = \text{ISO power} * \frac{\text{DF1} * \text{DF2} * \text{DF3} * \text{DF4}}{\text{DF5}}$ Eqn. 1		
Notes: - E12 filtration is preferred as it offers significant benefits and has proven industry experience. - Some GT Manufacturer/Suppliers include some inlet and outlet losses in ISO power. In such situations applied correction factors for inlet and outlet losses should be adjusted to compensate for losses already covered by GT Manufacturer/Supplier. For example, an application has normal inlet system and a WHRU in exhaust. GT Manufacturer/Supplier includes 100 mm inlet loss and 100 mm outlet loss in ISO power. In this case applied derating factors need to be adjusted as follows: Inlet: Nominal pressure drop = 120 mm, Covered by manufacturer = 100 mm. Therefore applied derating factor should be for remaining 20 mm, which is calculated as $[1 - (1.5/100) * (20/100)] = 0.997$ Outlet: Nominal pressure drop = 300 mm, Covered by manufacturer = 100 mm. Therefore applied derating factor should be for remaining 200 mm, which is calculated as $[1 - (0.5/100) * (200/100)] = 0.99$		

Description of derating factors (DF)	% loss on power	Derating factor
3. The derating factor for process compressor power margin does not relate to a real reduction in power supplied by gas turbine. It covers the uncertainty in process compressor power estimation and should be applied to process compressor power. For most applications (especially LNG refrigeration compressor trains) the general practice is to utilize all available power from the gas turbine and size process compressors accordingly. Therefore for ease of calculation this factor has been applied to gas turbine power. 4. For application where this is not valid (e.g., a GT - Compressor - Generator train), this power margin should be applied to process compressor power only and not to the full gas turbine power. 5. Direct driven auxiliaries (e.g. shaft driven pumps) are normally included in the ISO rating. 6. For Gas turbines drives for process compressors in a fouling duty, process compressor power consumption might increase over time due to fouling (loss of efficiency). An additional margin might be required during GT selection to cover this.		

3.2 STANDARD PACKAGES

Gas turbines are generally offered as standard packaged prime movers developing a rated power at a rated speed, and are not normally custom-built to meet the user's particular power requirements.

1. Changes to the standard package shall only be considered if Safety, Integrity and Reliability/Availability are at stake.

If a compact design is the standard package for the Manufacturer/Supplier, changes can have a significant cost impact.

4. INSTALLATION

1. Refer to DEP 31.29.00.10-Gen. and DEP 61.10.08.11-Gen. for requirements for installation.
2. In deciding upon the location of a gas turbine installation, consideration should be given to maintenance and process operations.
3. The specification of overhead cranes shall be based on equipment classification and full life-cycle costing and evaluated against the practicality of performing maintenance with a mobile crane.
4. The overall lay-out of a gas turbine train installation shall allow safe access to equipment (allowing the operators/maintenance staff to perform their duties) and to overhead lifting equipment where provided.
 - a. There shall be no unguarded floor openings around machines.
5. Plant electrical and electronic equipment, including cabling and junction boxes, shall not be installed in areas subjected to heat in excess of their design capability.
 - a. Conduit and cabling shall not prevent maintenance access.
 - b. Conduit and cabling should be supported by side panels or brackets that need not be removed for maintenance.

6. Suitable lay-down areas shall be provided close to the gas turbine installation for components dismantled during maintenance.

Such components include air inlet filters, sections of acoustic enclosure, casings, ducting, covers, rotors, complete aero engine removal and sections of exhaust diffuser.

7. The required floor loading shall be suitable for the maximum maintenance weight to be handled.
8. All special lifting equipment and special tools required for turbine maintenance shall be listed and provided in a box.

If gas turbine downtime is a critical factor, it could be beneficial to specify that all tools for maintenance are provided in a walk-in type container.

9. The capability for modular change out of fuel delivery equipment, lubrication systems, hydraulic systems, valves and junction boxes should be maximized in design.

With compact installations, there is a tendency for Manufacturer/Suppliers to position fuel delivery equipment, lubrication systems, hydraulic systems, valves and junction boxes between the main beams of the base plate of the gas turbine.

- a. Before positioning fuel delivery equipment, lubrication systems, hydraulic systems, valves and junction boxes between the main beams of the base plate of the gas turbine, a review shall be completed to ensure that all components will be accessible without first having to dismantle adjacent equipment.
10. Safe access to the air filter shall be provided for inspection and for changing the replaceable filter elements.

On large filters, several levels of access are required to reach the replaceable elements.

 - a. All designs shall be reviewed to ensure that air filter maintenance can be carried out with the gas turbine in operation.
 11. The lay-out of auxiliary equipment shall permit easy and safe access to all components for operations and maintenance by the provision of permanent steps and platforms and adequate clear floor space.
 12. The design shall be such that, for normal operation of the gas turbine, it is not necessary to enter the acoustic enclosure.

Therefore all operational and maintenance items are specified to be accessible or can be viewed from outside the enclosure.

Entering an aeroderivative gas turbine enclosure is an unsafe act due to the extreme high noise level in an enclosure; the noise could be in the range of 120 dB(A) sound pressure level.

5. GAS TURBINE ENGINEERING REQUIREMENTS

5.1 GENERAL

This section defines minimum engineering requirements to be verified by the project with the gas turbine Manufacturer/Supplier and Sub-suppliers.

5.2 ENGINE SPEED AND ROTATING ELEMENTS

5.2.1 Operating speed

1. Variable speed may be considered for process control purpose with multi-shaft engines.