MANUAL

COMBUSTION GAS TURBINES - SELECTION, TESTING AND INSTALLATION

DEP 31.29.70.11-Gen.

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DESIGN AND ENGINEERING PRACTICE

PREFACE

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APPENDICES

1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the type selection, testing and installation of combustion gas turbines for mechanical and generator drives and for hot gas generation.

This DEP is a revision of the DEP of the same number dated March 1985.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIOP and SIEP, the distribution of this DEP is confined to companies forming part of or managed by the Royal Dutch/Shell Group, and to Contractors and Manufacturers/Suppliers nominated by them (i.e. the distribution code is ”C”, as defined in DEP 00.00.05.05-Gen.).

This DEP is intended for use in oil refineries, chemical plants, gas plants and, where applicable, in exploration and production facilities.

If national and/or local regulations exist in which some of the requirements may 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 as regards safety, 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 with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party which 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/Vendor** is the party which manufactures or supplies the turbine and provides associated back-up services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates, and ultimately pays for, the project. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant, authorised to act for 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.

The word **Shall** indicates a requirement.

The word **Should** indicates a recommendation.

1.3.2 Specific definitions

Vital, Essential and Non-essential service	For definitions and explanation of these services see Appendix 1.
Continuous service	A service in which it is not expected that the turbine will have to be stopped/started during normal plant operation.
Intermittent service	A service in which it is expected that the turbine will be started/stopped at unspecified intervals, e.g.: - automatic starts and stops at intervals by process operated controls; - manual starts and stops at intervals by manual control for batch processes.
Hostile environment	Locations where the air is contaminated with aerosols, salt, sand or dust, e.g. offshore or in a desert area.
Prototype	A prototype is 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. NOTE: In this definition it is the the gas turbine itself that is considered and not the entire package unit with auxiliaries.
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.
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.
ISO rating*	The ISO rating of a gas turbine is its rating at 15 °C ambient temperature, 1013.25 mbar atmospheric pressure and 60% relative humidity, with zero inlet and exhaust pressure losses.

NOTE: * The above three definitions are independent of the requirements for a service life of 20 years and for at least 3 years of uninterrupted operation, as specified by DEP 31.29.60.30-Gen. and DEP 31.29.60.31-Gen.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced by this DEP are listed in (10).

2. GENERAL REQUIREMENTS

2.1 SELECTION AND EVALUATION

The selection of gas turbines and the technical evaluation of bids from gas turbine Vendors shall be based on the requirements of this DEP together with DEP 31.29.70.31-Gen.

DEP 31.29.70.31-Gen. covers both industrial heavy duty gas turbines, Type H, and modular or aero-derivative gas turbines, Type G, as designated by the American Petroleum Institute.

Since there is continuing development in gas turbine design and improvement of efficiency, care should be taken to ensure that prospective Vendors do not exceed the proven ratings of their respective designs in their efforts to achieve competitive tenders.

The examination and evaluation of tenders for gas turbines for hostile environments shall be particularly rigorous. In particular, a specific air quality assessment should be conducted to determine the dust particle size, concentration/type of particular pollutants and local climate in order to specify and select the best filtration requirements for such environments.

Vendor shall be responsible for conducting the air quality assessment and the resultant required adaptation of the filter design.

2.2 RANGE AND VARIETY OF GAS TURBINES

Every effort shall be made to minimise the level of spares by rationalising the variety of makes and types of gas turbines, the associated drives and auxiliary equipment.

This rationalisation shall be applied stringently provided it does not prevent selection of the most suitable gas turbine for the specified operating conditions and does not increase the total cost of ownership (TCoO).

2.3 PROTOTYPE GAS TURBINES

Selected equipment shall in all respects be within the range of the Manufacturer's proven experience and shall not involve the use of prototype designs or components.

The development of gas turbines is largely centred around the development of hot parts and their thermal capabilities. Specific focus is therefore required on the Manufacturer's experience of these parts and the proposed firing temperature.

The Vendor shall list in his proposal all changes which are not proven in similar machines produced over the last 5 years or with which less than 100 000 fired hours have been accumulted in all machines.

Any change is subject to Principal's acceptance and proven alternatives may be requested.

2.4 OPERATING REQUIREMENTS

All particular operating requirements that the gas turbines may need to fulfil shall be specified in the data/requisition sheet. Parallel operation, if required, shall be stated. Special attention shall be given to 'off-design' conditions which may occur during start-up and shutdown procedures associated with the particular applications of the gas turbine. The exhaust mass flow and temperature under part-load conditions are important considerations for gas turbines in combined heat and power installations, especially if exhaust heat is to be used for steam raising without supplementary firing of the boiler.

2.5 SPARES INVENTORY

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

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

Alternatively, it could be worthwhile to share gas generators or spare rotors with other users or to enter into a procurement initiative whereby the Vendor 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 may be necessary.

Spare gas generators or rotors shall be stored in nitrogen-pressurised metal containers. The pressurised containers are supplied as original equipment by the gas turbine Vendors.

2.6 COMPLETE UNIT RESPONSIBILITY

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. For a mechanical drive configuration this shall be the driven equipment Manufacturer. By mutual agreement with the Principal, the driver Vendor may be responsible for the total train. For an electrical generator drive configuration a complete package may be ordered from the gas turbine Manufacturer or from a packager or its associates, who have been approved for this purpose by the Principal.

3. TYPE SELECTION

3.1 GENERAL

There are two types of combustion gas turbine:

- industrial combustion gas turbines, designated Type H by the API, and
- aero-derivative gas turbines, designated Type G by the API.

As a general rule for process applications, the industrial gas turbine is preferred to the aero-derivative gas turbine. The latter should not be excluded if the total cost of ownership is expected to be lower or if allowable mass and available space are limited, such as in offshore or oil field applications. The reliability and availability of the specific gas turbine under consideration shall be key criteria for determining the plant on-stream time and the total cost of ownership.

Aero-derivative gas turbines require premium gas and liquid fuels. If the gas turbine fuel may be a crude oil, residual fuel oil, very lean gas, refinery mix gas or a gas that is subject to changes of Wobbe Index of more than 10%, then industrial gas turbines shall be specified.

For mechanical drive applications where a wide range (70% to 100%) speed control is required, the selection of a two-shaft industrial gas turbine, if available in the power range, shall be given preference.

For generator drives, a single-shaft industrial gas turbine should be selected, since the greater inertia inherent in this type gives improved frequency stability and it is simpler and more easily maintained.

The use of aero-derivative or two-shaft industrial gas turbines as generator drives requires careful matching of governor and alternator characteristics in order to achieve satisfactory frequency stability. A load co-ordination study should be undertaken before proceeding with such applications.

Recuperative (regenerative) gas turbines should only be considered if the selected recuperative heat exchanger has proven reliable in similar applications. With the increasing need for environmentally friendly operation and optimum efficiency, waste heat recovery from the hot gas for steam generation or process heating should be considered. It shall be ensured that failure of the waste heat recovery unit and/or its control system does not adversely affect process or power reliability and availability.

3.2 SITE-RATED POWER

The site conditions of elevation, humidity and ambient temperature shall be taken into consideration together with the type of fuel (gas/liquid) and combustors and the power requirements of the driven equipment in order to arrive at a realistic site-rated power (rating) of the gas turbine.

Apart from the ambient condition deratings, the 'site rating' should be adequate to cover losses due to:

API 617 power margin for centrifugal compressors	4%
Unrecoverable gas turbine losses	
• air compressor fouling	2%
• ageing	3%
Inlet system (including air filter) and outlet losses (each)	2%
Waste heat recovery units in exhaust	2%
Main gearbox	2%
Driven auxiliaries (normally included in the ISO rating)	

Note: For process compressors in a fouling duty, additional margin may be required to cover future efficiency losses.

As a general rule there shall be a power output margin of at least 10% between the demand of the driven equipment and the power of the on-site gas turbine when in new and clean condition to cover fouling, wear and tear and control margin. Note that the power extracted by the auxiliaries, directly driven from the gas turbine, is not always included in the Vendor's standard information sheets.

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.

ISO ratings of the various makes and models shall be clearly correlated with the load envisaged, since Manufacturers 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.

A flat rating, where the power output offered is independent of ambient temperature, is not acceptable. Flat rating offered by some Vendors assumes a constant power output irrespective of ambient temperature, compensating for the increased firing temperatures at high ambients 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.

3.3 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.

API RP 11 PGT gives general requirements and limitations in applying these standard turbine designs.

4. INSTALLATION

Unless otherwise agreed, the installation shall be in accordance with DEP 31.29.00.10-Gen and DEP 61.10.08.11-Gen.

The Vendor shall comply with these requirements and, to enable him to do so, all information relevant to the installation of the gas turbine(s) shall be given in the data/requisition sheets, or shall be stated in the enquiry or order.

In deciding upon the location of a gas turbine installation, consideration shall be given to maintenance and process operations.

The specification of overhead cranes shall be based on equipment classification and full life-cycle costing and shall be evaluated against the possibility of performing maintenance with a mobile crane. For offshore platforms the provision of hoisting facilities shall be evaluated on a case-by-case basis.

The overall lay-out of a gas turbine train installation shall allow safe access to all operating positions and to overhead lifting equipment if provided. There shall be no unguarded floor openings around machines.

Electrical and electronic equipment, including cabling and junction boxes, shall not be installed in areas subjected to excessive heat. Conduit and cabling shall not disturb maintenance access and shall preferably be supported by side panels or brackets that need not be removed for maintenance.

Suitable lay-down areas shall be provided close to the gas turbine installation for components dismantled during maintenance. Such components include sections of acoustic enclosure, casings, ducting, covers, rotors and sections of exhaust diffuser.

The design of the enclosure shall allow quick and easy access for maintenance so that components can be removed safely and quickly. Care shall be taken at the design stage to ensure that sufficient space is available for maintenance.

The required floor loading shall be suitable for the maximum maintenance weight to be handled.

All special lifting equipment and special tools required for turbine maintenance shall be listed and provided in a box by the Vendor. If gas turbine downtime is a critical factor, it may be beneficial to specify that all tools for maintenance shall be provided in a walk-in type container.

With compact installations, there is a tendency for Vendors to position fuel scheduling equipment, lubrication systems, hydraulic systems, valves and junction boxes between the main beams of the base plate of the gas turbine. Before accepting such arrangements, a careful review is essential to ensure that all components will be accessible without first having to dismantle adjacent equipment.

With certain designs of gas turbines, attention is required in the design stage to the accessibility of ports for borescope inspection and combustion monitoring thermocouples. These shall be readily accessible without the need to remove gas turbine accessories.

For modular or aero-derivative gas turbines, the design of the acoustic enclosure shall make provision for ready access for lifting equipment so that the GT engine itself or components requiring inspection and/or maintenance can be readily removed and replaced. It is particularly important to ensure that lubricating/hydraulic oil pumps can be hoisted out for maintenance.

Safe access to the air filter shall be provided for inspection and for changing the replaceable filter elements or for desludging the oil-wetted rotating screen oil bath. On large filters several levels of access are required to reach the replaceable elements. All designs shall be reviewed to ensure that air filter maintenance can be carried out with the gas turbine in operation.

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.

Control equipment which requires setting or adjustment while the gas turbine is running shall be installed outside the acoustic enclosure.

For normal operation of the gas turbine, it should not be necessary to enter the acoustic enclosure and the arrangement of the installation should take this into account. All local instrument gauges and indicators should be placed on an external auxiliary skid or be readable from outside the enclosure.

Lubrication and control oil filling points should similarly be located outside the enclosure.

A 3-D CAD model shall be submitted for each proposed installation to assist with evaluating accessibility for operation, maintenance and construction.

For EP applications such requirement shall be indicated in the specification.

5. NOISE LEVELS

5.1 LIMITS

The Contractor shall comply with DEP 31.10.00.31-Gen. and thereby communicate to the Vendor the specified noise limitations by using data sheet DEP 31.10.00.94-Gen., which forms part of the requisition. The Vendor is responsible for ensuring that these equipment noise limitations have been specified.

5.2 INFORMATION TO BE SUBMITTED WITH THE TENDER

The Vendor shall submit guaranteed sound power levels and sound pressure levels (including octave band spectrum) of the equipment together with any relevant information as requested in data sheet DEP 31.10.00.94-Gen. The Vendor shall indicate what special silencing measures, if any, are proposed in order to meet the specified levels.

5.3 GENERAL

Noise control measures shall cause no hindrance to operations nor any obstruction to routine maintenance activities.

All definitions, notations, measuring equipment, measuring procedures, test reporting, calculation methods and calculation procedures shall be in accordance with EEMUA 140.

6. OIL TANK VENTS

Oil tank vapours shall be routed away from the gas turbine and its air inlet system. Where appropriate, the use of a finned vent tube should be considered, to provide the maximum cooling effect. The vapours shall then be routed to the coalescer, which should be a high-efficiency unit. Coalescers should be of the mechanical separation type and may need a by-pass to allow cleaning of the coalescer while continuing operation of the gas turbine. The oil condensed in the coalescer shall be piped back to the oil tank or to disposal. The remaining oil vapours from the coalescer are normally routed to the outlet of the exhaust stack where the vapour is burnt.

Oil vapour from tanks containing synthetic fire-retardant lubricants shall be kept separate from mineral oil vapour.

7. MATERIALS

7.1 GENERAL

Materials of construction of the gas turbine casing, internals and hot service components shall be the Manufacturer's standard for the specified operating conditions. Materials used for the remainder of the package shall as far as practical be in accordance with DEP 30.10.02.11-Gen. and DEP 30.10.02.31-Gen.

Copper and its alloys shall not be used in the presence of hydrogen sulphides, acetylene, ammonia, ammonium chloride or mercury.

Materials for components in contact with gas shall conform to NACE MR0175 if the level of H_2S exceeds the levels specified therein.

For marine environments, air compressor blades shall be made from a material resistant to the corrosive atmosphere or shall have a corrosion-resistant coating.

The Manufacturer's selection of materials/coatings for rotor and stator blading shall be submitted to the Purchaser with the tender. Any deviation from the originally specified materials after an order has been placed shall be submitted to the Principal for approval.

7.2 MATERIALS CERTIFICATION

The requirements for materials certification for gas turbines are given in DEP 31.29.70.31-Gen.

Where positive identification of a material is considered essential, as may be the case for special alloys, a higher level of certification should be considered. In this event, this requirement shall be indicated on the data/requisition sheet.

8. STARTING DRIVES

8.1 GENERAL

The starting and acceleration of a combustion gas turbine and its driven equipment to self-sustaining speed may be accomplished by means of a steam turbine, electric motor, gas/air expansion starter, hydraulic motor or internal combustion engine.

The Purchaser shall specify the type of starting system, e.g. diesel engine, electric motor, gas expander etc. An electric motor shall be the first option as starter. Due to local circumstances or other requirements (such as black starts) and in remote locations, alternative starters with more complex support systems may be required. The starter shall be designed for and capable of consecutive crank washing and 3 start attempts followed by a complete start cycle.

When determining the location of the starter, it shall be ensured that there is sufficient access for operation and maintenance.

8.2 GAS EXPANSION STARTERS

Particular requirements apply to the selection of gas expansion starters.

The gas supply to a gas expansion starter shall not be taken from the manifold for the gas turbine fuel gas supply, since the sudden reduction of pressure during the starting cycle for one gas turbine can cause the shutdown of other running gas turbines connected to the same manifold. A completely separate starting gas manifold shall be provided.

The starting gas valve shall be a three-way quick-acting valve, with the starter side vented to flare or dedicated safe vent when the valve is not actuated. Flexible elements in the valve shall be compatible with the fuel gas.

The gas expansion starter exhaust shall be isolated by a double valve system when connected to a common vent or flare system. Each gas expansion starter shall be provided with its own exhaust. The exhaust should be as short as possible, discharging in a location and direction which minimises hazards.

If safety considerations do not permit the use of a hydrocarbon gas as the power medium, an air start system should be considered. There are several proprietary systems as used for aero-engine starting which are available. The reliability of such air start systems shall be examined for each installation.

8.3 HYDRAULIC MOTORS

Where a high-power gas turbine is to be installed in a location in which space is limited, it may be difficult to accommodate a starter unit of the size required. In such cases a hydraulic motor starter should be considered. The prime mover for the hydraulic starter can be located in a convenient place which may be at some distance from the gas turbine. Hydraulic motors are compact and can provide the high power needed for starting large engines. Hydraulic motors and related oil systems shall be suitable for consecutive crank washing and 3 start attempts followed by a complete start cycle.

8.4 DIESEL ENGINES

Diesel engine starters shall be suitable for the hazardous area classification in which they are located.

Diesel engines shall be procured from Manufacturers with adequate service facilities locally available.

The fuel tank shall be sized for at least 4 hours' continuous operation of the diesel engine.

9. FOUNDATIONS, BASEPLATES AND MOUNTINGS

Gas turbines and their immediate accessories, transmission and driven equipment shall be mounted on rigid steel base plates. These are often sectioned to facilitate transportation. They may also be fabricated by different Manufacturers.

The separate baseplate support and swivel plates shall be epoxy grouted directly to the concrete foundations, allowing alignment corrections between auxiliary drive, gas turbine and driven equipment.

The Purchaser shall state in the data/requisition sheets or purchase order the type of foundation on which the base plate is to be installed. Where possible, and to minimise cost, the gas turbine and driven equipment shall be installed at grade. Alternatives are a concrete foundation, a steel structure or an offshore platform. There are different techniques for installation on each type of foundation.

Supporting the base plate on a concrete foundation is best achieved using the 'Chock-and-Block' method illustrated in Appendix 3, with spherical shims and shimpacks > 25 mm. On offshore platforms and floating production and storage offtake systems (FSPOs) the design of the machinery modules can be significantly simplified if the gas turbine driving train baseplate design is rigid and supported on a three-point mount. Alignment of the driving train is then unaffected by platform movements. The gas turbine train shall be suitable for continuous operation under a tilt angle of maximum 3 degrees. A full structural analysis shall be performed to achieve the required stiffness of the baseplate. A complete stress analysis of connecting pipe work and cables shall ensure that no distortion will occur.

For FPSOs the maximum tilt angle can be substantially larger than 3 degrees. The actual static and dynamic displacement requirements for these applications shall be specified separately. As a guide, turbine-driven generator sets in essential services must be capable of normal operation up to and including the maximum angles specified, while generator sets in non-essential services and mechanical-drive packages and compressor sets in process services must be capable of surviving, but not necessarily capable of operating, at these maximum angles.

Offshore weight restrictions shall be observed in the design. Three point mounts and torque tube designs are preferred. An arrangement where the driven equipment can be attached to the driver base plate to create a three point mount is also acceptable.

Installation of the driving train on a steel structure allows tuning to avoid vibration transmission. A complete structural analysis shall be performed for offshore installations and shall be considered for land installations.

10. CONTROLS AND INSTRUMENTATION

10.1 GENERAL

Gas turbine Manufacturers supply a complete control and monitoring system with their gas turbines as part of the package. It is not possible to dispense with their control systems because they contain such essential items as the governor control, fuel scheduling, combustion monitoring and gas turbine safety circuits. The process or driven equipment controls are frequently integrated with the gas turbine control panel.

The gas turbine control panel shall be capable of receiving signals from the plant control panel. The plant control system shall also be capable of receiving signals from the gas turbine control panel. The gas turbine control panel can be installed in the field auxiliary room (FAR) at a limited distance, not exceeding 200 m, from the gas turbine. The start up, shut down, control and monitoring shall normally be accomplished from the remote plant control room via the gas turbine control panel. In special situations such as testing these activities may be conducted from the gas turbine control panel. The gas turbine Manufacturer shall condition the signals in his control panel to interface with the Purchaser's control and monitoring system.

Instrumentation and control systems on gas turbines can adversely affect the reliability of the complete unit. Particularly in packaged gas turbine units, where a standard gas generator may be equipped with alternative instrument and control systems, the generator's reliability and reference performance in similar applications shall be scrutinised. If redundancy and fault tolerance of the control and safeguarding systems are required, these features shall be embodied from the instrument sensor up to and including the controller and safeguarding logic.

10.2 CONDITION MONITORING SYSTEM

It shall be specified in the data/requisition sheet which instrumentation and sensors shall be provided to perform on-line condition monitoring of the gas turbine and its auxiliaries.

Monitoring sensors should be compatible with on-site centralised monitoring facilities if these are already provided.

The condition monitoring systems shall include gas turbine performance monitoring modules that trend aerodynamic performance degradation of the turbine and the air compressor in particular. Specific pressure transmitters may need to be installed in the air compressor inlet in order to obtain a reliable analysis.

Manufacturers' standard vibration transducers shall be used for safeguarding duties whilst eddy current probes may be added for monitoring purpose. The vibration probes shall be placed at suitably selected locations that do not increase the likelihood of oil leaks, unreliable measurements or probe failure. Whenever possible, probes shall be mounted so that they can be assembled and disassembled without major strip down of gas turbine components.

11. INLET AND EXHAUST SYSTEMS

11.1 AIR INTAKE SYSTEM

11.1.1 General

The location of the combustion air intake shall be carefully selected so as not to shorten the life of the gas turbine. Satisfactory access shall be provided and no undue hazard shall be created. If flammable gasses are detected in the combustion air inlet, the safeguarding system shall shut down the gas turbine. The combustion air intakes should be as close to the gas turbine as possible, to minimise cost and any power reduction due to pressure loss. The intake shall be located in a non-hazardous area or a zone 2 area; it shall not be located in a zone 0 or a zone 1 area. The intake shall not be placed beneath a roof of any building within which flammable vapours may accumulate. Process equipment, pipe flanges and open drains shall not be placed within 5 metres of the air intake. Careful consideration shall be given to the area classification surrounding the gas turbine installation.

If a previously untried air inlet configuration is to be used, a computational fluid dynamics (CFD) analysis shall be conducted to design out possible turbulence. The provision of scrolls in the air inlet is subject to the approval of the Principal.

A flammable gas detector should be installed in a fast loop in the air inlet. As shown in Appendix 2, which is typical, the inlet to the fast loop shall be a perforated tube over the full height of the intake (because flammable gas in the atmosphere may be stratified, the sampling system described will avoid spurious signals).

The entire air inlet system shall be made from AISI 316L stainless steel, because systems using coatings on carbon steels have been found to fail over time. The cost of repair of these systems exceeds the first cost of stainless steel. In specific cases the Principal may deviate from this requirement, and this shall be stated on the data sheet.

It is essential to ensure that the entire air intake system is completely leak-free. Mastic sealants dry out and fail and should be avoided. All welding shall be continuous. Bolted assemblies shall use an elastomer sealant and the pitch of the bolting shall ensure that an airtight joint is achieved. The roofs of intake housings and the intake ductwork shall be sloped to allow rainwater to run off. All joints in these components shall be fully welded or, if bolted, shall have lap joints not flanged joints. These provisions shall prevent rainwater leakage into the air intake (in winter the resulting icicles can severely damage the gas turbine and rain is also a heavy pollutant carrier). Drain connections shall be fitted with suitable sealing connections, i.e. no open drains. The above considerations apply equally to the gas turbine enclosure and ventilation air intakes. Where mass and space are restricted, extracting the ventilation air downstream of the first stage of combustion air filtration may be considered. Ventilation and air ducting shall be removable in sections for easy disassembly of the sound hood.

The distortion of ducting flanges for flexible joints (rubber bellows) shall be kept within the tolerances set out by the Manufacturer of the joint. Undue stressing of the joint will lead to leakages and shorten the lifetime of the joint. During the evaluation specific attention shall be given to the selection of a suitable type and make of joint.

11.1.2 Air compressor cleaning

Air compressor cleaning facilities shall be installed for both on-line washing and off-line crank soak washing. The required cleaning method shall be stated on the data sheet. Operation of the washing system shall be done outside the enclosure.

Appendix 5 gives recommendations for the use of water-based and petroleum-based detergents.

11.2 EXHAUST SYSTEM

The exhaust stack should terminate at a sufficient height to prevent recirculation of the hot gas plume into the combustion air intake, the ventilation air intake or the inlet of surrounding process equipment. If aircooler banks are located close to the gas turbine exhaust stack, a simulation test shall be specified to determine the minimum stack height to prevent recirculation. The top of the stack should normally be at least 12 metres above the centre line of the gas turbine.

The design of the exhaust stack shall prevent rain ingress into the gas turbine exhaust collector. The typical designs illustrated in Appendix 4 are effective.

Routing of the exhaust ducting and the position of the stack need careful consideration in order not to restrict access for maintenance by means of overhead cranes and lifting gear.

For offshore platforms, it shall be checked that the hot gas plume cannot be recirculated into other areas of the platforms under any of the weather conditions likely to be experienced and that no hazard can be caused to helicopter approach paths. In most cases, model testing or computer simulation will be needed to ensure that these requirements are met.

11.3 EXHAUST EMISSION

Proven NOx, CO, CO2 and SOx reduction measures shall be applied. In most cases, the primary focus shall be on the reduction of CO2 and NOx emission. Dry low NOx (DLN) combustors or catalytic combustors of proven design shall be used for NOx reduction. Only if even greater NOx reduction is required should additional systems in the GT exhaust be considered.

12. COMBUSTION AIR FILTRATION

12.1 GENERAL

High-quality combustion air is essential if the gas turbine performance is to be maintained. Contaminants in the combustion air stream cause fouling, corrosion, premature blade failure and hot gas path failure. Gas turbine Manufacturers shall provide detailed data sheets on the allowable maximum levels of airborne contaminants that can be tolerated by their machines without affecting component life. These limits shall be adhered to.

The local environmental conditions at the installation site shall be appraised by means of an air quality assessment to determine the best air filtration system. This appraisal shall take into account the interaction with any industrial plants in the vicinity which may occasionally emit particles to which the filtration system is sensitive. There are specialist contractors who are able to sample the air and determine the nature, particle size and quantity of pollutants in the atmosphere. Generally, the air filtration requirements for industrial, desert or marine installations are quite different.

All filter arrangements shall start with a inertial water separator in wet climates or an inertial dust separator in dry climates. The further specific filter type should be discussed between the Principal and the Supplier and depends on the local climate. Before an order is placed, the make and type of filter shall be agreed.

All air filters shall have air intakes fitted with a rain hood forcing an upward air flow into the filter housing. This is effective in reducing rain and snow ingress into the air filter and shall be supplemented with a suitably designed louvre design that effectively prevents water mists from entering the filters. For filters in dry climates a dust louvre system shall also be specified. There shall also be at least two active filter stages. The underside of the air intake shall not be less than 3 metres above grade level (this ensures that no heavy dusts and insects can enter the filter).

The air inlet filter shall be designed for a maximum pressure drop of 15 mm water gauge with clean filters and an average air velocity through the filter of 1.5 m/s. The delta P measuring system shall be suitably located so that a representative result is obtained for the filter condition.

Where space is limited, and for offshore applications, the velocity may be higher but only up to a maximum of 3.0 m/s, and it shall be accepted in this case that there will be a reduction in filter efficiency and more frequent gas turbine shutdowns for cleaning. For offshore installations, air filtration units may operate at higher velocities resulting in smaller filter units, if economically justified.

Pulse filters shall not be used in a refinery or industrial atmosphere where an increased quantity of aerosols, soot and dust can be expected. Pulse filters should only be considered in environments with a prevailing low humidity due to their sensitivity to caking of dirt when wet. The removal of dirt during cleaning of part of the filter should be routed away from the operating filter sections. Pulse filters are not recommended offshore.

12.2 ANTI-ICING SYSTEMS

Air filters can ice up when the air is saturated with water and the ambient temperature is between minus 5 and plus 5 degrees Celsius. The icing-up of the gas turbine air intake filter and ducting causes flow disturbances and may even completely block the air intake filter. Icing-up may also occur at the inlet guide vanes of the compressor.

To prevent icing-up of gas turbine intake systems, either bleed air from the compressor or spent hot sealing air may be used which is mixed with the cold air drawn in via the air intake filter. Using bleed air from the compressor reduces the power output and efficiency of the gas turbine, whilst using spent sealing air does not. Package ventilation may be considered for anti icing purposes. To improve engine efficiency a humidity/ambient temperature control shall be fitted in the anti ice control system.

Due consideration shall be given on the gas turbine's anti-icing requirements and instrumentation requirements to provide a reliable system.

12.3 SHUTTERS

Gas turbines subject to windmilling should be fitted with shutters on the air intake or exhaust to prevent windmilling when idle. When the shutters are closed, the gas turbine and its ducting system should be continuously purged with heated dry air to prevent condensation.

13. FIRE PROTECTION

13.1 GENERAL

DEP 80.47.10.31-Gen. shall apply in conjunction with this DEP.

13.2 VENTILATION DAMPERS

The use of ventilation system dampers should be avoided as far as possible. If dampers are used, their design shall be simple and reliable, and if possible based on gravity closure by weights. The recommended extinguishants are heavier than air and remain within the enclosure upon release, unless there are unsealed openings in the gas turbine base plate. If an ignition should occur within the gas turbine acoustic enclosure with the ventilation dampers closed, the over-pressure is liable to burst the access doors of the enclosure.

13.3 EXTINGUISHING SYSTEMS

Water deluge systems shall not be fitted on gas turbine installations (a deluge of water on to a hot gas turbine casing will cause extensive damage).

‘Inergen’ or CO_2 gaseous fire extinguishing systems shall be used. Inergen is an agent composed of nitrogen, argon and carbon dioxide, which after a release sufficiently reduces the concentration of oxygen to stop a fire but is safe enough for humans to survive and function in a normal matter. The mixture of nitrogen, argon and carbon dioxide stimulates respiration systems so that survival in a low oxygen environment is possible. Inergen is therefore safer than CO_2 and shall be the preferred choice for new applications provided appropriate refills are locally available.

Release of the agents can be automatically and/or manually initiated.

For offshore applications, fine water mist systems could be considered if space is at premium. These systems require a large quantity of nozzles and tubing to be an effective extinguishing system at the source of the fire.

13.4 ENCLOSURE SURVEILLANCE

For remote unattended locations, the use may be considered of closed circuit television (CCTV) to monitor equipment within an acoustic enclosure. Zoom, pan and tilt controls shall be provided from the control room. With low light image intensification, CCTV is a useful tool for operators to survey remote equipment.

14. ACOUSTIC ENCLOSURES

14.1 GENERAL

Gas turbines emit a noise level which is higher than that normally permitted and acoustic enclosures are invariably required. Particular precautions are required for the enclosure, in which high temperatures may prevail and flammable vapour may be present.

The acoustic enclosure may include the gas turbine, its auxiliaries and driven equipment, or it may have separate compartments for each of these individual units. The nature of the installation, the type of driven equipment and the composition of any flammable vapour which could be released within the enclosure will generally dictate whether the enclosure shall be continuous or shall have separate compartments.

Ergonomic and noise control requirements require the use of off-base mounted turbine enclosures to provide more space for maintenance and better control of noise emission instead of the type of enclosures formerly used which were close-fitted and mounted on the turbine baseplate). The enclosure shall be equipped with strategically located lifting beams on which a chain block can be fitted for minor maintenance activities.

14.2 ACCESSIBILITY

The design of the acoustic enclosure shall be checked to verify that it does not restrict access for operation and maintenance of the enclosed equipment. The design of doors and removable sections shall be such that equipment may be removed for maintenance without excessive dismantling of the acoustic enclosure. Cables and junction boxes shall not be routed through or supported by the roof of the compartment, to allow rapid top access after quick release of the roof.

A sensible design of the enclosure can significantly reduce the downtime for maintenance inspections. Care shall be taken to ensure that there are adequate doors to allow emergency escape of personnel from the enclosure. There shall be no obstructions between any working area and an escape route. The design drawings shall indicate critical locations during operation and the escape routes from these locations.

14.3 VENTILATION

The acoustic enclosure shall be ventilated to remove heat generated by the equipment and to dilute the concentration of any flammable vapour which may accumulate within the enclosure.

If internal barriers segregate the enclosure into separate compartments it shall be ensured that each compartment is adequately ventilated.

The ventilation air shall be filtered and extracted downstream of the filters. A typical arrangement is shown in Appendix 2.

Whether the acoustic enclosure shall be pressurised above or below atmospheric depends on the area classification surrounding the gas turbine installation and the local conditions. The enclosure shall definitely be pressurised above atmospheric pressure if the surrounding area is classified as Zone 1 or 2. The normal ventilation pressure shall not be less than 5 mm water gauge, either positive or negative, and it should not exceed 20 mm water gauge positive or negative. It shall be verified that the enclosure can withstand the worst case ventilation pressure when two fans are running and the compartment outlet dampers are closed.

Side panels which have to be removed for maintenance or on-stream inspection shall be hinged.

A limit switch shall be connected to the ventilation fan discharge damper. A running indication light shall be provided on the fan motor. These safeguards shall start the second fan upon flow failure, and shut down the gas turbine if ventilation air flow is not restored within 30 seconds.

14.4 AREA CLASSIFICATION WITHIN ACOUSTIC ENCLOSURES

The area classification within the enclosure shall be determined from the following criteria:

- the area classification surrounding the gas turbine installation
- the type of fuel used for the gas turbine.

If either the area surrounding the gas turbine installation is classified as a hazardous area or the gas turbine is fuelled by gas, the acoustic enclosure shall be classed as a Zone 1 area when the enclosure ventilation is out of operation. At all times when the ventilation system is in operation, the enclosure shall be designated as a non-hazardous area.

All electrical equipment within the ventilation system shall be suitable for operation in Zone 1 areas, to allow these motors to continue operating inside the enclosure when the ventilation system is down.

15. FUELS AND FUEL SYSTEMS

15.1 FUEL SELECTION

The characteristics of the intended fuel(s) shall be stated in the data/requisition sheets, since the prospective gas turbine Manufacturers are required to confirm the suitability of the intended fuel(s) and to support this with evidence of prior experience with fuels of similar quality and composition, see ASTM D 2880. The Manufacturer shall also advise on any treatment needed for the intended fuel(s) to render them suitable for the proposed application. It shall be verified that the smoke emission of the intended fuel is within local regulations.

In marginal cases, it should be investigated whether identical fuels have been used by other operators and any specific design requirements determined, especially in relation to trace elements. Gas turbine hot parts are particularly sensitive to alkaline metals such as sodium and potassium. Other elements may have additional restrictions due to environmental emission limits and the general corrosion requirements of downstream systems. Fuels containing heavy metals may require additional fuel treatment systems. All Manufacturers have comprehensive guides to suitable fuels and these guides include advice on the permissible level of contaminants and concentration of corrosive agents which can be tolerated in a particular fuel. This advice should be followed in reaching agreement with the gas turbine Manufacturer on these levels and concentrations for the intended fuel(s).

15.2 GAS FUELS AND SYSTEMS

A gas fuel with a variable composition should be avoided. Where gas fuels of varying compositions may be used, the implications shall be discussed in detail with the prospective Vendor. The variations in Wobbe index shall be indicated for all operating conditions, including start up, so that the fuel and combustion system can be designed to cover all these cases. Particular attention shall be paid in the design of the system to ensure that at start up the gas arrives at the correct temperature and pressure at the gas turbine flange.

WOBBE INDEX

The Wobbe Index relates the heating value of a gas to its density and is important for combustor design. The basic relation is:

WI = CV / √(SG)

where WI = Wobbe Index

CV = calorific value on volumetric basis

SG = specific gravity (with respect to air)

However, there are a number of variations possible using different units for calorific value, expressing heating value on a Gross or Net basis, or on a mass basis instead of volume basis, and relating to standard conditions, which then requires inclusion of absolute temperature in the formula. As an example the WI used by gas turbine Manufacturers is defined as follows:

WI = LHV/√((Tg + 273) *SG) in SI units

where:

LHV = Lower Heating Value in J/m^3 at ISO conditions (15 °C and 1.013 bar (abs))

Tg = Gas temperature in degrees Celsius

SG = Specific gravity relative to air at ISO conditions.

The Wobbe Index is not dimensionless and so the calculated value is dependent on the units and formula used. Therefore, the Manufacturer/Supplier of the gas turbine shall state clearly the definition of Wobbe Index used and specify the variations in Wobbe Index acceptable both as an absolute variation and also as a rate of change. This is of particular importance where the design includes a facility for switching from one fuel gas type to another (e.g. a back-up supply).

It is of paramount importance that any possibility of liquid entrainment or condensate formation in the fuel gas supply is totally eliminated. The system shall be designed to prevent this occurring under all conditions, in particular the formation of condensates in fuel gas lines under idle conditions.

The fuel gas temperature at the gas turbine stop valve should be at least 20 °C above the dew point of the gas and shall not exceed the maximum fuel gas temperature specified by the Manufacturer under any operating condition. Heating may be necessary to comply with this requirement.

Only the fuel governor valve may be located within the acoustic enclosure as it should be close to the fuel gas manifold. The manually-operated shut off valve shall be located so that the gas turbine can be shut down and manually isolated in the event of an emergency.

15.3 LIQUID FUELS AND SYSTEMS

Care shall be taken to ensure that distillate fuels do not become contaminated with salts or water. If the fuel has been transported in seagoing tankers, it will almost certainly be contaminated with salts. Settlement alone is then not sufficient to remove these salts. The fuel shall be washed with potable water and then centrifuged to reduce the salt concentration to a level which will comply with the Manufacturer's specification for the fuel.

Heavy fuel oils and crude oils may require treatment for the removal of salts and particulates and for inhibiting vanadium. These fuel oils will often also require heating for proper atomisation, and arrangements for heating the fuel distribution system and providing trace heating for all fuel lines shall be provided.

If for start-up and shutdown procedures the gas turbine Manufacturer requires a start up gas or light distillate fuel oil for flushing the fuel system, provisions shall be made to meet this requirement.

Where several gas turbines grouped together are to be liquid fuelled, a centrally located fuel oil processing, pumping and accumulator system should be considered for supplying fuel to each gas turbine at sufficient pressure for atomisation without further pumping.

15.4 DUAL FUEL SYSTEMS

Governing systems are available to permit either a liquid fuel, a gas fuel or a combination thereof to be fired.

Where dual fuel or combined fuel systems are offered, the Vendor shall demonstrate the adequacy of the fuel nozzles and governing system in achieving transfer from one fuel to another and back again, under all conditions of turbine load.

15.5 POWER AUGMENTATION

In many applications, power augmentation by steam or water injection may be desirable to enhance the power output. In such cases it shall be verified whether similar applications are in operation with adequate availability, and the effect of this system on the maintenance requirements and the lifetime of parts shall be taken into account. It should be recognised that steam or water injection may require make-up facilities to be provided.

16. INSPECTION AND TESTS

16.1 GENERAL

Any special inspection and test requirements above those of DEP 31.29.70.31-Gen. shall be specified in data/requisition sheet DEP 31.29.70.93-Gen. or stated in the purchase order.

16.2 TEST REQUIREMENTS

16.2.1 General

It is seldom necessary to specify full performance testing of a standard proven train arrangement and/or proven design of gas turbine. Only if no references can be give for the configuration or rating of a particular design should the gas turbine be performance tested against a dynamometer or in a string test combined with the driven equipment.

If specified, standard production performance tests shall be conducted in accordance with either ASME PTC 22 or ISO 2314. Selection of the test code and details of the test shall be agreed between the Purchaser and Vendor.

16.2.2 Combustion tests

If the fuel to be used at site is unusual in any respect, e.g. a fuel gas with a low heating value, a combustion test shall be specified, see DEP 31.29.70.31-Gen.

16.2.3 Complete unit or 'string' test

For units in vital or non-spared essential services a complete unit test (full load or part load) shall be considered. The string testing of first units shall be considered. If such a test is required it shall be specified in the data/requisition sheet.

For power turbines used in combination with aero-derivative hot gas generators, a slave hot gas generator may be used instead of the contract hot gas generator. The number of starts and cumulative running hours as from ex-works delivery of these hot gas generators shall be taken into account in assessing the guarantee period.

The site of the complete unit test shall be mutually agreed between the Purchaser and Vendor. If a gas turbine train is installed in a pre-fab module, then the complete unit test shall be carried out in the module at its fabricator's yard, supervised by the Vendor of the gas turbine package. For this test the fuel used for the gas turbine shall be similar to that intended for the installation on site.

All details of the complete unit test shall be agreed with the selected Vendor before the contract is awarded. The site proposed for carrying out the test should be inspected to ensure that all facilities required for running the test are actually available and that the instrumentation and equipment provided for analysing the test results will be properly calibrated prior to the test.

All auxiliaries forming part of the supply shall be used during the string test.

17. REFERENCES

In this DEP reference is made to the following publications.

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

SHELL STANDARDS

Index to DEPs and Standard Specifications	DEP 00.00.05.05-Gen.
Requisitioning binder	DEP 30.10.01.10-Gen.
Metallic materials - selected standards	DEP 30.10.02.11-Gen.
Metallic materials - prevention of brittle fracture	DEP 30.10.02.31-Gen.
Noise control	DEP 31.10.00.31-Gen.
Installation of rotating equipment	DEP 31.29.00.10-Gen
General-purpose steam turbines (amendments/ supplements to API 611)	DEP 31.29.60.30-Gen.
Special purpose steam turbines	DEP 31.29.60.31-Gen.
Combustion gas turbines (amendments/ supplements to API 616)	DEP 31.29.70.31-Gen.
Field inspection prior to commissioning of mechanical equipment	DEP 61.10.08.11-Gen
Fire-fighting systems	DEP 80.47.10.31-Gen.

Data/requisition sheets:

Data/requisition sheet for equipment noise limitation	DEP 31.10.00.94-Gen.
Data/requisition sheet for gas turbines	DEP 31.29.70.93-Gen.

NOTE: Data/requisition sheets are contained in the requisitioning binder (DEP 30.10.01.10-Gen.).

AMERICAN STANDARDS

Packaged combustion gas turbines	API RP 11 PGT
Centrifugal compressors for petroleum, chemical and gas service industries	API 617

Issued by
American Petroleum Institute
Publications and Distribution Section
2102 L Street Northwest
Washington, DC 20037
USA

Gas Turbine Power Plants	ASME PTC 22

Issued by
American Society of Mechanical Engineers
345 East 47th Street
New York, NY 10017
USA

Specification for Gas Turbine Fuel Oils	ASTM D 2880

Issued by
American Society for Testing and Materials
1916 Race Street
Philadelphia, Pa. 19103
USA

Sulphide stress cracking resistant metallic material for oil field equipment	NACE MR0175

Issued by
National Association of Corrosion Engineers
1440 South Creek
Houston, Texas 77084,
USA

BRITISH STANDARDS

Noise procedure specification	EEMUA 140

Issued by:
Engineering Equipment and Materials Users Association.
45 Beech Street
London EC2Y 8AD
UK

INTERNATIONAL STANDARDS

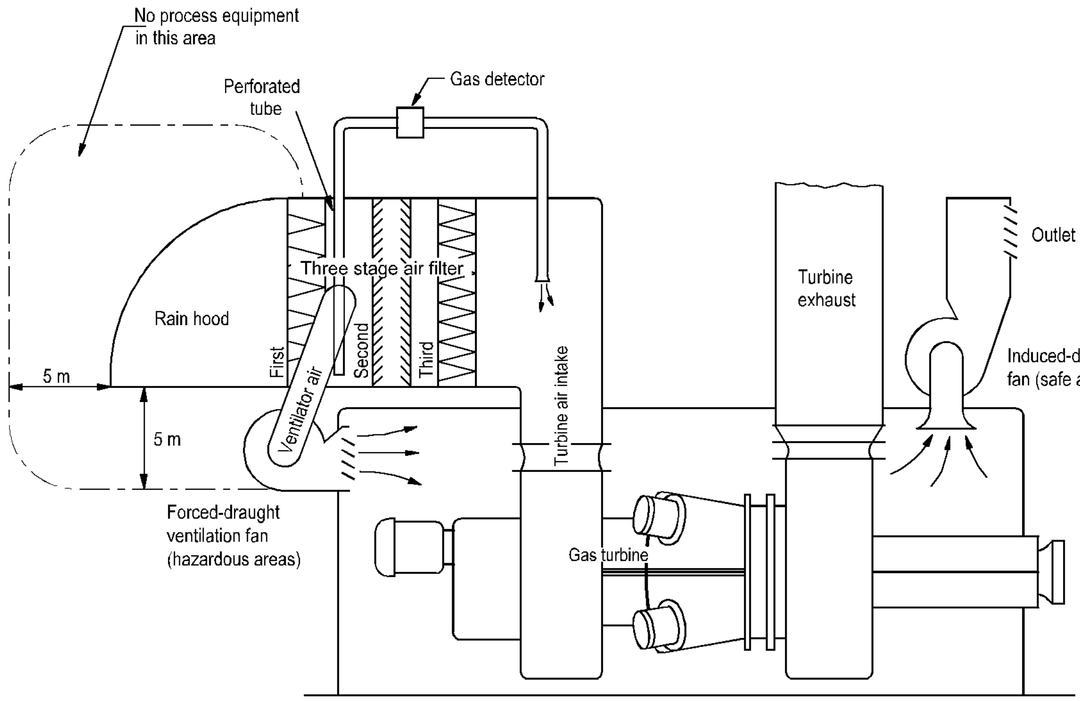
Gas turbines - acceptance tests	ISO 2314

Issued by:
Central secretariat of ISO
1, rue de Varembé
1211 Geneva 20
Switzerland

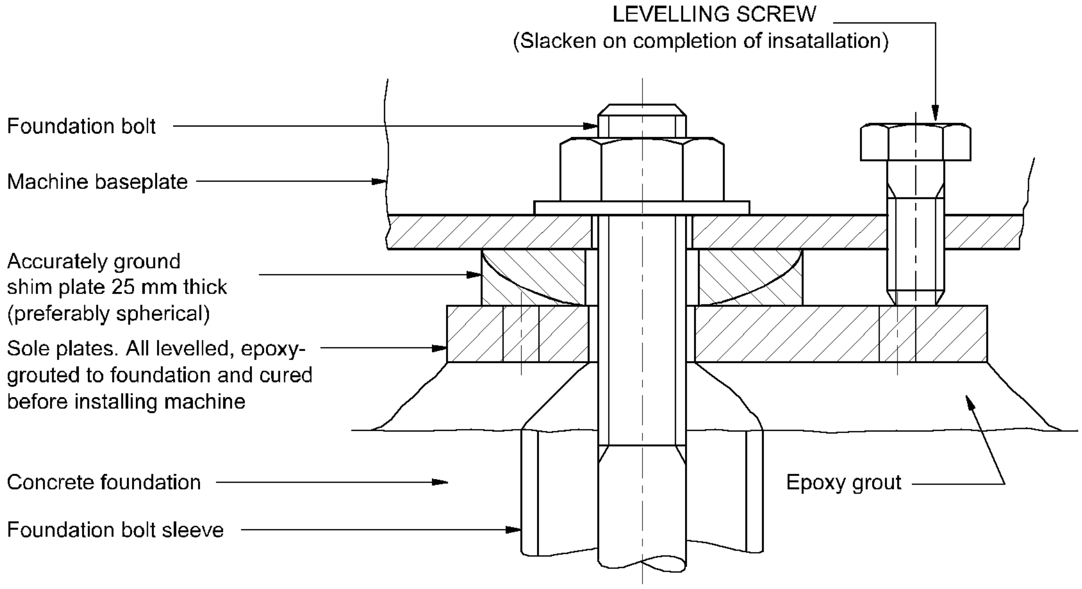
APPENDIX 1 DEFINITIONS AND EXAMPLES OF VITAL, ESSENTIAL AND NON-ESSENTIAL SERVICES

	SAFETY EQUIPMENT	**OTHER EQUIPMENT**		
	SERVICE CATEGORY			
	VITAL	**ESSENTIAL**		**NON-ESSENTIAL**
		Non-spared equipment	**Spared equipment**	
Definition	A service in which failure of equipment causes an **unsafe condition** of the plant or installation resulting in **jeopardy to life** and/or **major damage** (fire, explosion etc.).	A service in which failure of equipment renders a plant or process unit **inoperable** or **reduces performance** to a level **unacceptable** to the Principal.	A service in which failure of equipment renders a plant or process unit **inoperable** or **reduces performance** to a level **unacceptable** to the Principal.	All other services.
Selection Criteria	Equipment shall be adequately spared to ensure 100% availability of the service under all circumstances	A decision not to install spare equipment is based upon economic considerations and proven equipment availability. Non-spared equipment availability may be upgraded by means of additional Capex to match required plant availability.	Installed spare equipment is normally selected where potential losses due to equipment outage greatly outweigh equipment Capex. Sparing philosophy shall be economically evaluated and is typically 2x100% or 3x50%.	Economic evaluation required to justify spared equipment.
Driver Selection Criteria	Independent power sources shall be selected to ensure 100% service availability		Independent power sources may be selected, for start-up and utility availability reasons	
Examples	- *firewater pumps with diesel and motor drives;* - *ESD systems;* - *EIA compressor.*	- *HCU feed pump;* - *HCU recycle compressor;* - *FCCU main air compressor;* - *FD and ID fans.*	- *BFW pumps;* - *fractionator bottom pumps;* - *fresh gas compressors (HCU).*	- *drinking water pumps;* - *sewage pumps.*

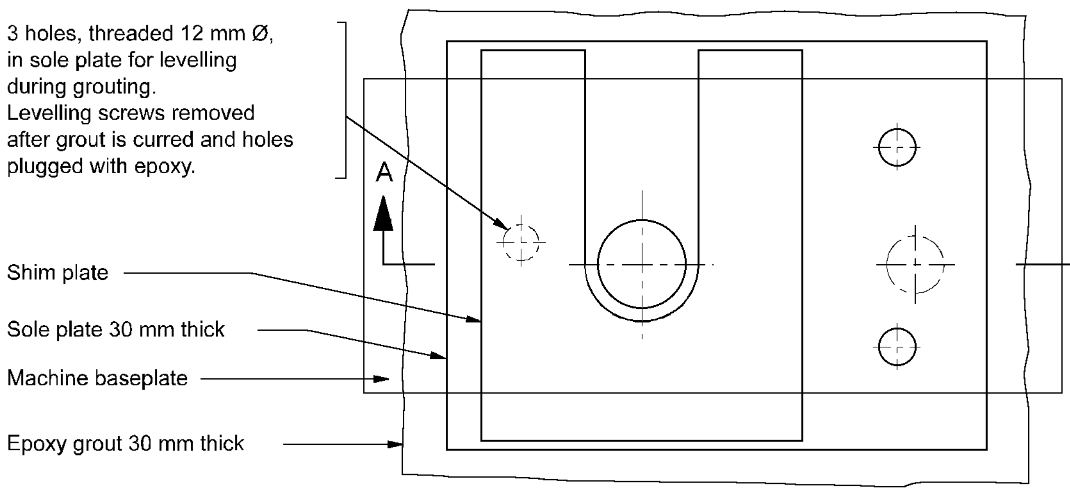
APPENDIX 2 GAS TURBINE ENCLOSURE VENTILATION



APPENDIX 3 TYPICAL ARRANGEMENT FOR BOLTING BASEPLATE TO FOUNDATION



SECTION A-A



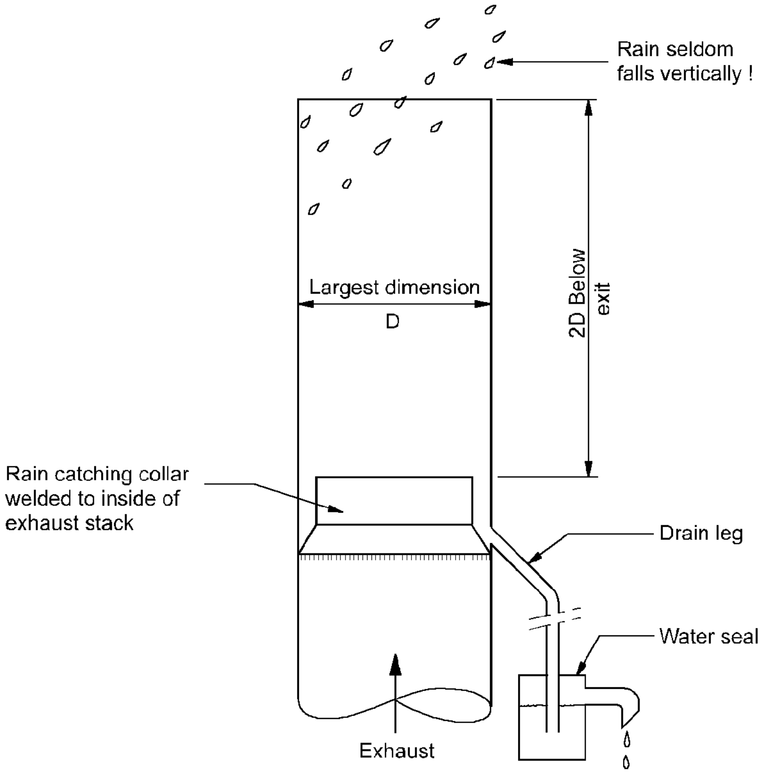
PLAN

(Baseplate omitted for clarity)

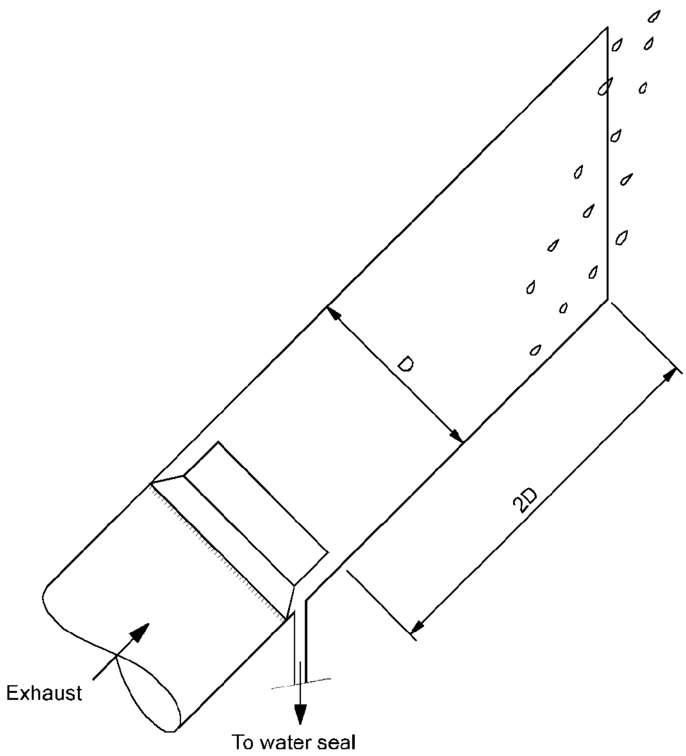
Notes:

1. Intermediate supports between foundation bolt locations as necessary.
2. Upon final levelling of machine measure exact shim thickness required and grind accordingly.
3. Fill remaining voids with Portland cement grout.

APPENDIX 4 EXHAUST STACK RAIN CATCHER



A. Vertical stack installation



B. Inclined stack installation

APPENDIX 5 GAS TURBINE WASHING

Key points to note for gas turbine washing:

- On-line washing may not restore full power since dirt may be moved down the compressor section settling at the high pressure sections.
- On-line washing needs to be supplemented with off-line washing to restore near-full power conditions. To be effective, on-line washing needs to be carried out frequently (once every 72 hours is typical)
- After each detergent on-line wash, a rinse wash should be applied to remove residue from the injection nozzles.
- Effectiveness of washing techniques depends on the type of fouling experienced, the selected washing liquid and the location of the injection nozzles.
- Solvent-based detergents are the most effective cleaning detergents. Water-based detergents are less effective.
- Logging of performance records before and after washing are crucial to the washing operation.
- Demineralised water with purity in accordance with Manufacturer's recommendations shall be used for washing. The critical issue is corrosion of the hot gas path due to impurities.
- Selection of washing detergent shall be based on the lowest possible ash content to minimise hot gas path corrosion. For off-line washing, waste water handling shall be considered.