TECHNICAL SPECIFICATION

GAS TURBINE HEAT RECOVERY STEAM GENERATORS

DEP 30.75.10.31-Gen.

November 1993
(DEP Circulars 43/96 and 20/99 have been incorporated)

DESIGN AND ENGINEERING PRACTICE

USED BY

COMPANIES OF THE ROYAL DUTCH/SHELL GROUP

PREFACE

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NOTE: In addition to DEP publications there are Standard Specifications and Draft DEPs for Development (DDDs). DDDs generally introduce new procedures or techniques that will probably need updating as further experience develops during their use. The above requirements for distribution and use of DEPs are also applicable to Standard Specifications and DDDs. Standard Specifications and DDDs will gradually be replaced by DEPs.

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APPENDICES

1. INTRODUCTION

1.1 SCOPE

This DEP is a revision of and replaces DDD 30.75.10.31-Gen. "Waste heat boiler installations for gas turbine exhausts" dated September 1988, gives minimum requirements for the design, engineering, inspection, site erection, start-up and performance testing of steam generators suitable for continuous operation in conjunction with a single gas turbine.

The DEP covers both unfired and fuel gas supplementary fired steam generators of both the forced and natural circulation type.

The installation shall comprise the equipment which shall be listed on a sheet entitled 'Scope of supply'. The limits of supply shall be listed and defined on a sheet entitled 'Terminal points'. For the guidance of the Principal, typical examples of a 'Scope of supply' and 'Terminal points' are given in Appendix 1.

To facilitate exchange and assessment of information by the Principal and the Manufacturer/Supplier, the data/requisition sheets (DEP 30.75.10.94-Gen.) shall be used, their purpose being described in (7). Any changes proposed after the order has been placed are subject to approval by the Principal.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIPM, the distribution of this DEP is confined to companies forming part of the Royal Dutch/"Shell" Group or managed by a Group company, and to Contractors and Manufacturers/Suppliers nominated by them (i.e. the distribution code is "F", as described in DEP 00.00.05.05-Gen.).

This DEP is intended for use in oil refineries, chemical plants, and gas plants and 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, 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 with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS AND ABBREVIATIONS

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** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

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

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific abbreviations and definitions

boiler: synonymous with steam generator.

boiler code: ASME I or BS 1113, as selected by the Principal.

fuel: all fuel gases specified by the Principal for firing in the boiler.

maximum continuous rating (MCR): the steam production under design conditions, measured downstream of the steam main stop/check valve and any desuperheater. It shall be measured upstream of any take-off of auxiliary steam.

peak load: shall mean 110% of MCR, unless otherwise specified on the data/requisition.

requisition: data/requisition sheets DEP 30.75.10.94-Gen. (9 sheets), which shall be used by the Principal and the Manufacturer/Supplier to specify the detailed requirements and proposals for a particular installation.

supplementary firing: the firing of fuel in the TEG to supplement the heat input to the boiler.

TEG: Turbine exhaust gas

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 in this DEP are listed in (8.).

2. DESIGN AND ENGINEERING

2.1 GENERAL

For design, fabrication, inspection and testing, the boiler code shall be followed for the main equipment, and ASME/ANSI B31.1 for the piping, supplemented or amended by this specification. Other codes may be used if local conditions make this desirable to the Principal. However, only one code shall be applied throughout.

The boiler shall be of the water-tube type and be suitable for continuous operation in conjunction with a single gas turbine. The boiler shall be suitable for outdoor operation.

Natural circulation boilers are preferred since it is considered that the absence of circulation pumps increases the reliability of the boilers. Forced circulation boilers, however, are an acceptable alternative in special circumstances, such as where space available is limited. In these circumstances, however, experience with the performance of circulation pump seals and thrust bearings shall be taken into account.

The Principal will normally specify the choice of natural or forced circulation of boiler water on the requisition (see 7.2). When not specified by the Principal, however, the choice of natural or forced circulation is left to the Supplier.

The design shall be proven in practice, robust and reliable. Safety, ease of operation, inspection, maintenance, repair and cleaning are of major concern.

In the case of a supplementary fired boiler, the MCR and peak load of the boiler shall be achieved over the turbine load range specified by the Principal on the requisition.

In the case of a boiler which is not to be supplementary fired, the boiler MCR shall be specified at the maximum continuous site load of the turbine. In such a case, the peak, base and minimum site loads of the turbine shall also be specified on the requisition.

All deviations of the Manufacturer/Supplier equipment from this DEP shall be listed by the Manufacturer/Supplier, and this list shall be forwarded with the completed requisition sheets 4 to 9.

The applicable local and national regulations shall be stated by the Manufacturer/Supplier on the requisition.

The Manufacturer/Supplier shall obtain all local code stamps and certificates needed.

Before the contract is awarded, the Manufacturer/Supplier shall satisfy the Principal that the circulation of water and steam is effective at all loads and that an even distribution is achieved of water, steam, TEG, air and flue gas over the various boiler parts.

The Manufacturer/Supplier shall give full details of the chemical and physical properties of the construction materials.

There shall be sufficient space and access for inspection, cleaning, removal and maintenance of such parts as tube bundles, headers, retractable burner parts, valves, pumps, fans, steam turbines and electric motors. Arrangements for the removal of tube bundles, as well as written procedures for such, shall be provided.

Where there is danger from freezing during operation or drainage of any part, protection against such freezing shall be provided.

There shall be adequate protection against the hazard of persons touching surfaces hotter than 60 °C. Normally this should be by a wire screen barrier.

Particular attention shall be paid to the possibilities for energy conservation measures, consistent with the specified fuels and operating conditions.

2.2 MAJOR HEAT TRANSFER EQUIPMENT

All metal surfaces in contact with flue gas shall be at a higher temperature than the highest dew point (acid or water as the case may be) which may occur during any of the operating conditions in combination with any of the fuels specified in the requisition.

Tube type and arrangement shall be selected for ease of construction, repair and access. Extended surfaces may be used. When not specified by the Principal, convective heat transfer equipment may have a rectangular or triangular tube pitch arrangement.

The design of tube banks and casing shall be such that the possibility of flue gas bypassing coils is minimised. Therefore the free space between the casing wall and the nearest tube should not be larger than the free space between adjacent tubes in the rest of the tube bank and, if possible, it should be less. If necessary, e.g. in the case of using triangular tube pitch, metal strips may be welded to the wall to reduce the flow gap. Attention is also drawn to the avoidance of vortex shedding in the tube bank design, see (2.2.9).

Restriction orifices for equalizing flow distribution over parallel tubes shall not be used in any part of the boiler, superheater and economizer.

2.2.1 Combustion chamber

2.2.1.1 Uncooled combustion chamber

Where supplementary firing is limited to the extent that the calculated adiabatic flue gas temperature in the combustion chamber does not exceed 800 °C, then an uncooled combustion chamber may be applied. This temperature limit may be extended to 850 °C if the Manufacturer/Supplier can produce evidence of the proposed design type operating satisfactorily at this hotter level with an uncooled combustion chamber. The capability of the auxiliary burners operating in this hotter environment shall be included in this context.

Other requirements for uncooled combustion chambers are covered in (2.4.1) and (2.4.2).

2.2.1.2 Furnace

If an uncooled furnace is considered to be inappropriate for the design and in any case where the adiabatic flue gas temperature in the combustion chamber exceeds 850 °C, a water-cooled furnace shall be applied. All walls of the furnace shall be water-cooled and the floor shall be partly or wholly covered by refractory.

Membrane-type walls are required, i.e. constructed from tubes and strips or tubes with extruded fins, either type to be welded over the whole length. Any attachments to membrane walls shall be made to the strips/fins between the tubes, not to the tubes. The construction shall be gas-tight.

The maximum local heat flux, under any operating condition, shall nowhere exceed 250 kW/m^2, based on the actual tube surface area exposed to the fire side, (see definition of cooling surface below).

For the calculation of the above quantities, the following definitions shall be used:

- The **furnace outlet** is defined as the plane through which the combustion gases leave the furnace as defined by the furnace volume and cooling surface below. Furnace outlet temperature and pressure are defined as the average gas temperature and pressure in this plane.

- The **furnace volume** is that which is enclosed by a geometrical surface comprising the furnace outlet and surfaces laid through the centre lines of those tubes which are exposed to direct radiation, and the surfaces occupied by the burners and refractory.

- The **cooling surface** as to be used in the calculation of the average heat transfer rate in the furnace, shall be defined as the actual tube surface (i.e. the half tube round surface) exposed to the fire side, which encloses the furnace volume described above.

The Manufacturer/Supplier shall also state on the requisition the total heat released

(kW/m^2) in the furnace at MCR, based on the above defined furnace cooling surfaces.

Furnace tubes shall be bent around observation ports, burner ports, etc., in order to make room for them.

No furnace tube shall be bifurcated, as this can lead to unstable flow. The furnace front wall may also be constructed with tube pairs of the membrane wall axially offset and with the strips/fins removed to allow turbine exhaust gas to enter the furnace between the tubes and evenly distributed over the front wall.

Burner lay-out and the path of the flue gas through the boiler shall ensure symmetrical heat flux loading of the furnace walls and all convection banks.

Flames shall not impinge on walls or any metal part during any operating condition, if such impingement causes deposits on surfaces and/or causes local heat fluxes which are in excess of the maximum allowable value.

2.2.2 Drums

The drum design and arrangement shall ensure the required steam and water separation, distribution and circulation in conjunction with the rest of the boiler.

The steam drum shall be outside the flue gas passage.

Drum internals shall be accessible and cleanable, and they shall be removable without damaging the drum. Manholes shall be elliptical or circular.

Tube stubs, suitably prepared for welding, shall be provided at the drums if tubes are to be welded at site.

Nozzles, stub ends for valves, fittings, mountings, tubes and anything to which drum internals, etc., are to be secured shall be shop-welded into place.

The length of the stubs shall be such that welding the tubes to the stubs will have no adverse effects on the drum or stub-to-drum connections.

Downcomers shall be connected as near to the bottom of the drum as possible to permit maximum use of drum water content.

The hold-up time between the water level at which the low water alarm is set and the low water instantaneous trip level shall be not less than 30 seconds under the condition where the boiler load is at MCR, the continuous blowdown is at its normal value, and there is no feed water intake; see also (3). The level difference between both normal-water level and low-water level, and normal-water level and high-water level alarm shall not be less than 150 mm. However, in the selection of level range and drum size, consideration shall be given to the possible transient conditions which may occur (e.g. the trip of a large consumer/generator) and the requirements to avoid a consequential high/low-level trip of the boiler.

The normal water level shall be indicated by engraved marks on the drum, and on the level gauges.

At all loads and maximum specified boiler water concentration, the specified purity of the saturated steam shall be attained.

The supply of feed water and the separation of steam and water shall occur evenly over the length of the drum. For feed water connection, see 2.2.6.3.

2.2.3 Superheater

The superheater shall have a substantially flat temperature-load characteristic, so that excessive desuperheating will not be necessary (see 2.2.4 for limits). If cooled screening is necessary to achieve this, evaporator tubes should be used for this purpose.

Where a membrane-type wall furnace is applied, superheater headers shall be outside the flue gas passage.

NOTE: Where header boxes, including the superheater header box in a membrane type wall furnace, are applied, they shall have drainage facilities and shall have adequate access for cleaning.

The steam flow shall be evenly distributed over parallel coils of the superheater(s) at all loads; see also (2.2.6).

The superheater shall be supported in a satisfactory manner so as to prevent distortion of tubes.

Drainable superheaters are preferred, but if superheaters with non-drainable loops are used, the method of protection against stand-still internal corrosion shall be described and equipment requirements for doing so shall be included.

Arrangements shall be made and instructions shall be given, to ensure adequate cooling of the superheater during start-up.

2.2.4 Steam temperature control

If it is necessary to control the temperature of the superheated steam, this control shall be accomplished by desuperheating, using spray water injection. Spray water shall be steam turbine condensate, condensed saturated steam from the boiler drum, or other water of equal purity and shall in any case come from a source protected against oxygen ingress. In order to ensure complete evaporation of the spray water, the steam temperature after desuperheating should be maintained at a minimum of 45 °C above the steam saturation temperature at normal MCR conditions. If the above spray water purity cannot be met, alternative drum attemperation may be considered but only if the degree of desuperheating required is so small as not to cause excessive boiling in the drum (which is detrimental to level control and steam/water separation). However, spray desuperheating is still a strong preference.

2.2.5 Natural circulation convective evaporator

Vertical tubes are preferred. However, other arrangements such as inclined tubes or combined vertical/horizontal tubes may be considered where clear evidence of successful application of the proposed natural circulation principle in a similar installation can be demonstrated.

2.2.6 Forced circulation convective tube banks

2.2.6.1 General

The water, steam and water/steam flows shall be evenly distributed over the parallel coils of the tube banks under all operating conditions. The number, size and arrangement of tubes, as well as the size and arrangement of headers and interconnecting piping pertaining to each parallel coil, shall be such as to ensure this.

Tube bank coils shall be of all-welded construction using welding return bends. 'Pulled' bends shall only be used with the Principal's permission; see also (2.7).

Welding return bends shall comply with ANSI B16.28, ANSI B16.9, or with BS 1640. They shall match the inside diameter of the connected tubes or pipes.

Inlet headers shall have hand-operated blowdown facilities for sludge removal and drainage. Headers shall not contain any non-drainable dead legs. Headers shall have welded end caps but allowance for metal loss which will occur after removing and re-welding end caps (for header inspection) shall be provided by means of a suitable and accessible extension of the end of the header; see also (2.2.7).

Tube bank coils shall be supported by a steel structure and shall not rest on internal insulation or cladding.

Coil supports shall be designed for the maximum load, including the load resulting from hydrostatic testing at site. The material shall be suitable for the most adverse conditions of service. For high-temperature service, cooled supports should be used.

Tubes shall be able to expand freely and independently of each other. The lateral movement of tubes shall be restricted in order to prevent dislocation of the tubes.

Spacer strips which are welded to tubes or fins shall normally be of the same material as the tube or fin. However, the Manufacturer/Supplier shall check whether the higher temperature of the strip requires a more heat-resistant material. Precautions shall be taken to avoid local overheating of tube walls.

Cross-over piping may be outside the boiler casing and shall be of the same material as the tube bank header upstream.

2.2.6.2 Convective evaporator

The convective evaporator shall have an upward steam/water flow. The circulation ratio shall be such that, at all boiler loads, the steam/water two phase mixture will not suffer phase separation, which would cause local dryout of the internal tube surface and subsequent salt deposition and/or tube overheating.

Water circulation shall remain sufficient to protect the coils:

- during the period between breakdown of one circulation pump and take-over by the spare pump.
- against the residual heat accumulated in the boiler during a complete power failure.
- during the transient following a gas turbine trip and switch-over to stand-by air fan operation where applicable (see 2.3.2).

2.2.6.3 Economiser

The economiser should not normally generate steam, as this may lead to maldistribution of water flow across the parallel coils.

An economiser which does not generate steam under any of the operating conditions shall be connected to the drum below the water level.

When an economiser is proposed which does generate steam under certain conditions, the supplier shall state in his tender the reasons, and provide evidence to the Principal that an examination has been made of the possible consequences of the steam generation on pressure drop, flow distribution/stability, stratification of steam/water and tube dryout/overheating, and internal erosion of tube bends from high steam/water mixture velocities.

Further, it shall be explicitly stated that this examination has revealed no condition which will adversely affect the equipment and its operation.

The steam drum connection for a steaming economiser shall be located lower than the centre line of the drum and upstream of the primary stage steam/water separators.

2.2.7 Casing

The casing shall have a design pressure based on the most severe combination of the wind pressure/suction, and the maximum operating pressure/vacuum in the casing.

There shall be no restriction to the free expansion of tubes or insulation and sheeting.

The casing shall be gas-tight.

The materials shall be adequate for the temperature of service.

All sheeting shall be sufficiently stiffened against damage during transport, erection, operation and vibration. Stiffening shall not interfere with the free expansion of the casing.

The casing design and construction shall facilitate the removal and/or installation, at site, of tube bank coils. The design shall further allow convenient access for cutting and re-welding of inspection end caps on headers.

The bottom shall be constructed from flat plate and sloped as necessary to provide for drainage during cleaning.

NOTE: Where header boxes, including the superheater header box in a membrane type wall furnace, are applied they shall have drainage facilities and shall have adequate access for cleaning.

Thermal insulation of the casing may be external only, or both internal and external as necessary, see (2.1) and (2.7.4).

The casing wall temperature shall be above the highest dew point temperature of the flue gas during any operating condition.

2.2.8 Observation and access

Observation windows shall be provided on supplementary fired boilers and shall afford an unrestricted view of all burners and flames. The windows shall also allow observation of all surfaces liable to flame impingement.

Where necessary, air purging shall be provided to keep observation windows sealed, clean and cool. The glasses shall have external covers to prevent cracking and shall be protected on the hot side by pivoting metal plates.

It shall be possible to renew the glasses during operation using purge air or the above-mentioned pivoting metal plates to prevent outward flow of hot flue gas.

Air for any of the above purposes shall not come from the instrument air system. Where required, the supply shall include two 100% duty purge air fans.

There shall be a sufficient number of access and inspection doors and access space for each section or tube bank of the boiler. For access doors in water tube walls a minimum free opening of 400 mm diameter (circular) or 400 x 400 mm (rectangular) is allowed, whereas in other duct walls a rectangular opening of at least 600 x 600 is required. The minimum distance for access between convective tube banks shall be 800 mm. For access to the drum, see (2.2.2).

2.2.9 Gas flow induced vibrations

The Manufacturer/Supplier shall include in his design all measures necessary to ensure that no part of the boiler installation and ductings shall be subject to excessive vibrations which are induced by gas flow and which may reduce the design lifetime of any part of the boiler and ductings, or create equipment noise exceeding the limitations as per (2.11). Where baffles are applied, they should be installed in line with the direction of gas flow.

Particular care shall be taken to ensure that the frequencies of gas vortex shedding from the tubes do not excite or resonate with the natural frequencies of the tubes in the boiler, superheater and economiser. In addition, such vortex shedding frequencies shall not excite or resonate with the acoustic frequencies of the boiler casing or ductings. That is to say that standing waves shall not be generated. The Manufacturer/Supplier shall state in his tender, the Strouhal numbers and the gas vortex shedding frequencies for each tube bank, as well as the lower natural frequencies of the tubes, and the acoustic frequencies of the boiler casing taking into account the presence of tubes. After contract award, the Manufacturer/Supplier shall submit all necessary calculations and these should indicate that resonances are not likely within the specified operating range.

In the event that, after initial start-up, it is found that corrective action to reduce vibration is necessary, it shall be the responsibility of the Manufacturer/Supplier to apply corrective measures prior to the hand-over of the boiler to the Principal. However, the corrective measures applied shall be subject to the approval of the Principal.

2.3 ROTATING EQUIPMENT

2.3.1 Circulating pumps

Boilers with forced circulation shall have two 100% duty circulating pumps, suitable for unrestricted parallel operation, for the circulation of boiler water at saturation temperature from the steam drum through the evaporator tube banks.

During normal operation one pump shall satisfy all requirements. The second pump shall be used only under abnormal operating conditions, or upon failure of the first pump.

The pumps shall be a horizontal heavy-duty centrifugal type. Selection shall be in accordance with DEP 31.29.02.11-Gen. Mechanical design, construction, shop inspection and testing of the pumps shall be in accordance with DEP 31.29.02.30-Gen.

To cater for power failures, unless specified otherwise by the Principal, the normally operating pump shall be steam turbine driven and the other one shall be electric motor driven. Drivers shall be capable of continuously developing 110% of the power required by the pump at peak load conditions of the boiler.

Steam turbine selection and testing shall be in accordance with DEP 31.29.60.10-Gen. The mechanical design and construction, shop inspection and testing of steam turbines shall be in accordance with DEP 31.29.60.30-Gen.

Electric motor drives shall be direct. Motors shall be in accordance with DEP 33.66.05.31-Gen.

2.3.2 Forced-draught fans

Standby forced draught fans which are intended to supply combustion air following a gas turbine trip shall not be supplied unless specified by the Principal. In that case they shall be in accordance with DEP 31.29.47.30-Gen. The Manufacturer/Supplier shall advise of any limitation on steam output of the boiler during operation with a standby fan, when this is applied.

The Manufacturer/Supplier shall also ensure that, during the switch-over to standby fan operation and vice versa, water circulation within the coils is maintained at a level sufficient to accommodate the heat load fluctuation without any mechanical damage.

2.4 TURBINE EXHAUST GAS AND FLUE GAS SYSTEM

2.4.1 Ducting general

Ducting, including bends, combustion chamber, if applicable, and boiler inlet box shall have a design pressure based on the most severe combination of the wind pressure/suction, and the maximum operating pressure/vacuum in the ducting.

The ducting shall be gas tight and smooth, and bends shall have rounded profiles and be fitted with guide vanes. Attention is drawn to the possible need to use vanes for correcting non-uniformities in the TEG flow at the GT outlet and/or boiler inlet. Guide vanes shall be designed to avoid resonance and the formation of eddies in the TEG stream; hence they shall have a smooth tapered leading edge. Attachment to ducting shall be by welding and allowance shall be made for differential thermal expansion. Particular attention shall be paid to the design of guide vanes when applied downstream of the combustion chamber in order to avoid thermal distortion of the vanes.

Ducting shall be sufficiently stiffened against mechanical vibration and distortion. Stiffening shall not restrict the free expansion of the ducting in any direction.

Effective vibration isolation from the gas turbine is particularly required.

All ducting, including the combustion chamber, if applicable, and boiler inlet box shall have a plate thickness of not less than 6 mm. Flanged connections shall be in accordance with Standard Drawing S 24.301, but bolt pitch shall be not more than 120 mm.

It shall be possible to drain all ducting.

All ducting shall be designed such that the free cross-sectional area provides stable gas flow and acceptable pressure loss. For noise limitations, see (2.11).

For the design of ducting upstream of fuel burners, the average gas velocity shall be limited to a maximum of 25 m/s.

Transition pieces between duct sections of different cross-sectional area shall be provided as necessary. These shall be designed with the objective of preventing flow detachment from the duct wall and providing the most economical pressure loss.

Diverging sections shall be designed commensurate with maintaining gas flow uniformity across the cross-sectional area. If necessary, guide vanes shall be used to maintain flow uniformity.

The Principal shall specify in the requisition the requirement, if any, for flow model testing of the ducting design.

Duct supports, expansion joints, brackets, baseplates, foundation bolts, nuts, packing, pipe supports, etc., shall be provided as far as required.

Duct supports shall be so designed as to remove all loads from the boiler casing. Sliding supports shall be designed to allow lateral and axial expansion movements of the ducting.

2.4.2 Boiler inlet ducting

The boiler inlet ducting shall comprise the complete ducting from gas turbine terminal point to boiler inlet, the ducting to the bypass stack and also, if applicable, the section for the supplementary firing burners.

The design shall be such that the TEG mass flow is evenly distributed across the burners of supplementary fired boilers. The distribution across the burners shall meet the requirements of the burner supplier as a minimum requirement (note that the Manufacturer/Supplier of a grid/matrix burner will specify this).

The design of the uncooled combustion chamber or boiler inlet box, as applicable, shall be such that the TEG is evenly distributed across the boiler inlet so that localised overheating of tubes by TEG side flow variations cannot occur.

Expansion joints shall be provided between the ducting and the bypass stack (if applied) and in the duct between the damper and the boiler inlet.

Expansion joints shall be of the bellows type, gas-tight and of a make approved by the Principal. They shall be of high temperature fabric, multi-layered and reinforced with stainless steel wires. The fabric shall be protected internally by insulation and metal sleeves. External protection shall be by stainless steel wire mesh and a ventilated rain shield. All metal parts in contact with the expansion joint fabric shall have rounded edges. The expansion joints shall be designed for continuous operation under the most severe operating conditions, and for ease of maintenance.

The boiler manufacturer shall be responsible for the design of the interface between gas turbine and boiler, and shall cooperate closely with the gas turbine vendor.

Access doors shall be provided, and be located such to give access to all sections of the ducting between the turbine and the boiler inlet. Particular note is made of the requirement for accessibility to guide vanes where applied.

Thermal insulation of ducting may be external only, or both internal and external as necessary, see (2.1) and (2.7.4). The duct wall temperature shall be above the highest dew point temperature of the TEG for any of the specified operating conditions.

2.4.3 Flue gas ducting

The flue gas ducting shall comprise the complete ducting from boiler outlet to stack and, if applicable, the ducting from the boiler to a separate economizer.

There shall be no dampers in the flue gas duct.

Expansion joints shall be provided in the flue gas ducting as necessary. The fabric type as described in 2.4.2 may be applied or, alternatively, the joints may be of the steel-bellows type with inner sleeves and shall be insulated externally to prevent the temperature of the metal in contact with the flue gas falling below the dew point of the flue gas.

Thermal insulation of flue gas ducting shall be external, see (2.1) and (2.7.4). Where insulation is for personnel protection only, heat shields are an acceptable alternative.

2.4.4 Dampers and isolators

2.4.4.1 General

Dampers are applied when one or more of the following functions are required:

- connection of the turbine exhaust to a bypass stack during start-up of the turbine
- TEG flow regulation for boiler start-up purposes.
- thermal isolation of the bypass stack (when applied) for energy conservation purposes during normal boiler operations.
- thermal isolation of the shut-down boiler during normal turbine operations.
- change-over of supplementary fired boiler from TEG to auxiliary air (when applicable).

Where a bypass stack is to be provided, a single blade damper shall be provided in the boiler inlet ducting.

Where safe access to the boiler for shut-down maintenance during normal turbine operations is required, a plate type isolator shall be provided downstream of the damper. Safe access isolation of the boiler is defined as 100% sealing efficiency at all turbine operating conditions.

Dampers and isolators shall be located upstream of the fuel burners.

2.4.4.2 Bypass/Change-over Dampers

Dampers shall be single blade change-over type.

For energy conservation reasons, the preferred sealing system is that which uses a double seal with purge air supplied between the seals under positive pressure. However, single seal dampers may be considered where the double seal system cannot be justified economically. The Manufacturer/Supplier shall state on the requisition the degree of gas flow isolation, as a percentage of TEG flow at maximum load, provided by the damper type proposed.

The shaft, blade and seals shall be of robust construction. Specifically, the design of the shaft and blade shall be aimed at the prevention of vibration or fluttering at any blade position under any operating condition.

Damper components shall not be subject to distortion or deterioration due to corrosive, high temperature or velocity conditions.

The damper operating gear shall be outside of the ducting, so as to be accessible for inspection and maintenance during normal boiler operations.

The damper shaft shall extend through the duct wall to external bearings and shall be sealed to prevent gas leakage. The damper shaft bearings shall be of the self-aligning and non-lubrication type. They shall be protected against environmental conditions. The design shall ensure that the shaft at the bearing area is adequately cooled to limit the temperature to within 50 °C of ambient. Attachment of levers to shafts shall be by means of sunk keys or rectangular ends. The shaft shall be marked to indicate the blade position.

It shall be possible to lock the damper in its closed position.

The damper blade shall not move under the effects of gravity or vibration.

Blade seals shall be all-metal, non-permeable and flexible, so as to accommodate thermal or other movements of the damper casing. Their sealing efficiency shall be assisted by the pressure difference across the blade.

Damper shaft drives may be electric motor or pneumatic actuator. Particularly in the case of supplementary fired boilers with an auxiliary air fan, the transition time for the TEG/air change-over damper must be as short as possible (e.g. approximately 15 seconds), in which case pneumatic actuators should be used.

A manual operation facility shall also be provided.

Electric motors shall be capable of developing at least 110% of the power required by the damper under the most severe operating condition. Further motor requirements shall be in accordance with DEP 33.66.05.31-Gen. All electrical connections and installations shall be suitable for the area classification and grouping specified in the requisition.

Equipment for manual operation shall be easily accessible. A shaft-mounted position indicator shall be included which is clearly visible during manual operation, and from grade level. Damper shaft drives shall be capable of transmitting at least 110% of the maximum motor torque. A disengaging clutch shall be incorporated to facilitate manual operation of the damper. Couplings in the transmission shaft(s) shall be all-metal and flexible. Shaft drives shall be protected by a rigid and rigidly mounted guard.

The maximum blade travel in both directions shall be controlled by limit switches. The mounting brackets of the limit switches shall be adjustable so as to allow the optimum closing positions of the damper blade to be set. The Principal shall specify the make and type of the limit switches.

Thermal insulation of the damper ducting may be external only, or both internal and external as necessary, see (2.1) and (2.7.4). The duct wall temperature shall be above the highest dew point temperature of the gas during any operating condition.

2.4.4.3 Spade plate isolators

See 2.4.4.1 for applicability of spade plate isolators.

The spade plate shall be inserted into the ducting joint downstream of the damper. It shall provide 100% gas-tight isolation.

The spade plate shall be thick enough and sufficiently stiffened to avoid distortion, and to withstand at least 1.5 times the bursting pressure of the ducting.

Unless otherwise specified, spade plates shall be of carbon steel and shall have a 2 mm corrosion allowance. They shall be provided with sufficient protection against corrosion.

Manual insertion of the spade plate shall be done from the top of the ducting by means of a chain block which shall not normally form part of the supply. The chain block shall be supported from a suitable overhead beam. Facilities for storing the spade plate securely while not in use shall be included. Insulation around the ducting in this section shall be suitably designed to allow easy access and minimise risk of damage during maintenance activities.

2.4.5 Stacks

The installation shall have its own boiler stack and, where specified, boiler bypass stack. Stacks shall be in accordance with DEP 34.24.26.31-Gen. If the stacks are excluded from the scope of supply, the boiler Manufacturer/Supplier shall provide the necessary information to enable the Principal to design them.

Stacks shall be provided with sufficient protection against corrosion, subject to approval by the Principal. If applied the bypass stack shall be protected against the ingress of rain by a water gathering rain hood or internal rims complete with adequate drainage facilities, and lifting lugs.

2.5 SUPPLEMENTARY FIRING SYSTEM

The Principal shall state whether the boiler is to be equipped with supplementary firing.

The supplementary firing system may be of a grid/matrix type, in-duct register type, or conventional register type adapted for TEG, whichever is most suited to the particular boiler design. Operating safety, reliability, turndown and the requirement to obtain a uniform TEG temperature distribution across the face of the boiler inlet, are features to be considered in the selection of the most suitable firing system.

The firing system shall be designed for gaseous fuel only. The fuel properties shall be specified by the Principal. If the fuel composition is variable, the range shall be specified by the Principal and the Manufacturer/Supplier shall design the system to achieve the required boiler performance with any fuel composition within the specified range. Also, safe start-up using any fuel composition within the specified range shall be possible unless stated otherwise.

Start-up of the firing system shall be automatic after the initiation signal is given by the operator.

The fuel supply to each independent burner system shall be safeguarded by a double block and vent tight shut-off valve arrangement functioning via the automatic safeguarding system. The vent shall terminate in a safe location and shall be protected against accidental isolation, the ingress of rainwater and accumulation of dirt.

In this context, an independent burner system shall be understood as being a single burner or a group of burners operated as one. For example, a grid burner comprising four burner rows is considered as one burner system if it is required that the four rows must always operate as a complete group. However, if the design also allows for the operation of two out of four burner rows (e.g. for turndown reasons), this would be classed as two burner systems comprising two rows each.

Where conventional register type burners are installed, each burner shall have its own fuel safety shut-off valve.

Where necessary, a start-up vent shall be provided. It shall terminate in a safe location and shall be protected against the ingress of rainwater. The start-up vent may be combined with the vent of the double block and vent system.

With the mode of supplementary firing proposed, it shall be clearly demonstrated on similar boilers in operation with similar supplementary fuels that:

- start-up is fast, safe and reliable;
- combustion is safe and stable at all turbine and boiler loads and load fluctuations;
- there is no flame carry-over into the superheater or convective evaporator sections of the boiler during any operating condition;
- operation of the burners is easy and safe;
- the flue gas mass flow and temperature distributions are uniform at the boiler inlet.

2.5.1 Burners

Fuel burners for supplementary firing of the boiler shall be of a type approved by the Principal.

All burners shall be capable of burning gaseous fuel exclusively.

Reliable operation of the burners, without risk of soot formation, harmful flame impingement, flame carry-over from the combustion chamber, or flame instability is essential. These requirements shall apply with any specified fuel, over the whole range of automatic control.

Provisions shall be made for the installation of flame supervision equipment on each register type burner and each row of a matrix burner; see also (3). In the positioning of the nozzles for this equipment, account shall be taken of the relative positions of each burner and of each ignitor or pilot flame in order to achieve good flame-eye discrimination.

The flames shall be stable and not blow off on any specified fuel in those cases when there is a minimum load on the burner together with the maximum turbine exhaust gas flow that can arrive at the burner, and in the event that highest possible fuel pressure occurs. This may happen if by accident the control valve opens fully. If the flames would otherwise be blown off when the burner is subjected to maximum fuel supply pressure, the control valve shall be provided with a maximum mechanical stop to prevent blow-off.

Burners and associated equipment shall be capable of withstanding the maximum TEG temperature when not firing, and maximum temperature/back-radiation when firing .

2.5.2 Ignition

Each register type burner, and each row of a matrix burner, shall be provided with its own ignition unit which shall include a fixed transformer and spark ignitor, an ignition burner and a flame safeguard, all suitable for intermittent operation in pressurized combustion chambers. The ignition burner shall be designed to have only one fixed position in the burner.

Provided that the dilution criterion is satisfied (see 2.5.3.1), ignition of an independent burner grid system should be carried out in one step i.e. simultaneous ignition of all burner rows which make up that independent burner system (see definition 2.5).

The Principal shall specify if these units are to be fed from an independent fuel supply system, for example a battery of propane cylinders located at ground level.

Pilot burners shall be supplied only if required by local or national regulations or if specified by the Principal. The design specification of pilot burners shall be approved by the Principal.

The flames of ignition and pilot burners shall be stable and not extinguish on any specified fuel, in the case of the maximum TEG flow arriving at the main burners.

Ignition units and pilot burners shall be of a type approved by the Principal.

2.5.3 Trial for ignition time

Ignition of supplementary firing burners shall be fully automatic and safeguarded by sequence control and flame detection devices. Supplementary fired boilers shall therefore be designed to comply with one of the trial for ignition time criteria as described in (2.5.3.1) or (2.5.3.2). These two criteria are given in order to cover the two basic types of supplementary fired boilers to which this DEP is applicable.

The final selection of the criterion to be used shall be approved by the Principal.

2.5.3.1 The dilution criterion

The dilution criterion shall be applied to boilers which are designed for flue gas flow in one direction only between inlet and outlet, and contain no dead pockets or areas of possible TEG recirculation in which explosive mixtures of fuel and TEG may accumulate.

In addition, these boilers shall be fired with matrix-type burners or equivalent which are designed to distribute the heat input evenly across the cross-sectional area of the combustion chamber inlet, thereby ensuring a good dilution of the fuel in the TEG stream at start-up.

In general, the total fuel gas flow at start-up shall be limited to the extent that the average fuel/TEG mixture remains well below the lower limit of flammability. A delayed ignition at the burner, therefore, (where fuel/TEG mixture local to the burner will be within the flammability region) will not give rise to ignition of the fuel/TEG mixture downstream. Hence the ignition time will not be critical. It also follows that matrix or equivalent burners may be started simultaneously provided that the dilution criterion is satisfied.

The dilution criterion defines the maximum % of stoichiometry allowed. This is not a fixed value and will vary according to temperature conditions prevailing in the combustion chamber and the composition of the fuel, in particular the hydrogen content. Thus, the dilution criterion is expressed as follows:

Max. % stoichiometry = 45 {(1200 - Tg)/1200} {H_2-factor} where Tg = TEG temperature in degrees C.

The factor 45 takes into account very poorly mixing burners fired on paraffins (C1, C2, etc.).

The temperature factor (1200 - Tg) corrects for the change in lower flammability limit with temperature.

The H_2-factor can be calculated as follows:

- when only the molecular weight (MW) of the gas is known and hydrogen (H_2) is present H_2-factor = (MW + 3)/25
- when only the %-vol. H_2 is known

  H_2-factor = 1 - 0.008(%-vol.H_2)
- when both the MW and the %-vol.H_2 are known, use the lower of the values found from MW and %-vol.H_2 given above.

- when the full gas composition is known, proceed as follows:

1) calculate the lower flammability limit (LFL) of the gas mixture as %-vol. in mixture with air

$$LFL = \frac{100}{\sum_{1}^{n} [\% - \text{vol.component}(n) / \text{LFLcomponent}(n)]}$$

hence

vol. fuel/vol. air = LFL/(100-LFL) = L

2) calculate stoichiometry of the gas mixture as %-vol. in mixture with air

$$STOICH = \frac{100}{\sum_{1}^{n} [\% - \text{vol.component}(n) / \text{STOICH } \% - \text{vol of component}(n) \text{ in air}]}$$

hence

From the above formulas for LFL and STOICH the H_2-factor can be derived as follows

$$H_2 - \text{factor} = \frac{2LFL}{100 - LFL} * \frac{100 - STOICH}{STOICH}$$

Appendix 2, Table A presents information on fuel components.

The exhaust gas from gas turbines is a mixture of air and inerts. The above criterion, however, is directly applicable because for a mixture of combustibles/inerts/air at LFL approximately the same %-vol. of combustibles is found as for the mixture without inerts. In fact the %-vol. combustibles in a mixture with inerts at LFL will be slightly higher as a result of the heat capacity of the inerts (CO_2 has the largest influence, then H_2O and N_2). The above is illustrated in Figures 1 and 2 in Appendix 2.

It should be noted that the calculated max.% of stoichiometry will apply to the worst possible conditions which can occur at start-up (highest temperature, highest hydrogen content) and the calculation of maximum permissible fuel rate will be based on the above calculated maximum % stoichiometry at the lowest TEG flow condition which may exist at start-up.

2.5.3.2 Energy criterion

The energy criterion shall be applied to boilers which are designed for flue gas flow in more than one direction between inlet and outlet, and for this reason contain dead pockets or areas of possible TEG recirculation in which explosive mixtures of fuel and TEG may accumulate. This criterion shall also be used where register type burners are used.

The energy criterion defines the maximum allowable energy input per unit volume of combustion chamber during the ignition period. This in turn fixes the maximum allowable time for burner ignition when the fuel rate to the burner at the start-up condition is known. This is defined as the trial for ignition time (TFIT).

The energy criterion aims to avoid an unacceptable pressure rise resulting from a delayed ignition of the combustible mixture in the combustion chamber. The extent of pressure rise is affected by flame speed (which is itself dependent on temperature) and fuel composition (fuel/TEG mixture assumed to be that giving rise to maximum flame speeds). The acceptable pressure rise is that which would not cause serious damage to the combustion chamber or connecting ducting (i.e. the flue gas side design pressure).

The maximum allowable energy input is defined as follows:

Max. allowed kJ/m^3 =

370.(V-factor).(°C-factor).(H_2 -factor).(Pdesign-factor)

in which:

V-factor gives the influence of the inscribed cylinder volume centred at the burner to be ignited, and of radius equal to the distance between the burner centre and the nearest wall.

V-factor = $(175/V)^{1/3}$ (V in m^3)

°C-factor gives the temperature influence on the flame speed.

°C-factor = (1200 - °C)/1200

For the temperature, the highest of the following temperatures is to be taken:

- temperature of the fuel
- temperature of the TEG
- temperature of the refractory in the combustion chamber
- temperature of the coils/waterwalls in the combustion chambers

In practice the refractory will cool down rather quickly after a flame-out and then the temperature of the coils/waterwalls can be taken in general as the start up condition.

H_2-factor gives the influence of the fuel gas composition on the flame speed.

- When only the MW of the gas is known and H_2 is present (it is assumed that no H_2 will be present when MW ≥ 22), then:
  H_2-factor = 1/(5.95-0.225 MW)

- When only the %-vol.H_2 is known, then:
  H_2-factor = 1/{1+0.045(% vol.H_2)}, see Figure 3, Appendix 2.

- When both the MW and the % vol.H_2 are known, use the lower of the values found from MW and % vol.H_2 given above.

- When the full composition of the fuel gas is known, then:

  H_2-factor = 1/{1+0.045%vol.H_2+0.023%vol.C_2H_2+0.005%vol.(C_2=+C_3=)+0.01%vol.CO}

NOTE: If inerts are present in the fuel, the flame speed is taken as the average for the combustibles only.

Pdesign-factor takes into account the mechanical design pressure of the heater casing and is as follows:

Casing mechanical design pressure, mbar (ga)	Pdesign-factor
10	0.25
20	0.60
50	1.00

100	1.40
200	1.75

A graphical presentation of the above is given in Figure 4, Appendix 2.

From the known (calculated) allowed kJ/m^3 heat input, the maximum allowable TFIT can be calculated as follows:

$$\text{TFIT max [in sec]} = \frac{\text{Heat input allowed (in kJ/m}^3\text{).V (in m}^3\text{)}}{\text{start load (in kg/sec).heating value fuel (in kJ/kg)}}$$

For a gas burner ignited at a fixed minimum stop burner pressure, the start load will be dependent on the actual composition of the gas.

$$\text{Mass flow: kg/sec fuel gas} = A\sqrt{MW}$$

and

$$\text{Heat release: kJ/sec} = A\sqrt{MW} * \text{LHV of gas}$$

with: A = a constant for the burner

LHV = lower heating value of the gas in kJ/kg

The TFIT can be calculated from the allowed heat input in kJ and the burner heat load at start-up in kJ/sec, and will be dependent on the gas composition.

The table below gives, relative to methane (CH_4), the heat release per second, the allowed kJ/m^3 and the maximum duration of fuel gas input (=TFIT).

Fuel Gas	**Heat Release per sec. (%)**	**Allowed kJ/m^3 (%)**	**Allowed TFIT in sec. (%)**
CH_4	100	100	100
100% H_2	85	18.2	21.4
75% H_2/25% CH_4	81.2	22.9	28.1
50% H_2/50% CH_4	86.8	30.8	35.4
C_2H_6	130	100	77
C_3H_8	154	100	65
CO	26.7	50	187
H_2S	44.3	50	113

Usually, the very minimum trial for ignition time acceptable under automatic start-up conditions is of the order of 3 seconds. However, prolonging the TFIT beyond 5 seconds is neither advisable nor necessary.

Therefore, no start-up trial shall last longer than 5 seconds whatever the calculated start-up trial time may be.

2.5.4 Burner piping

Piping and piping connections in the immediate vicinity of the burners are considered part of the burner supply. The lay-out shall be clear and simple and the piping shall be robust, accessible and vibration-free.

Piping shall not obstruct access doors, observation windows or burners, and shall not hinder operation of the boiler or burners. Piping shall not run through ducting.

Flexible metal hoses are permitted for the ignition burners, pilots and, if required, auxiliary air for the burners. Flexible hoses shall not be used in the main burner fuel lines unless differential expansion makes this a necessity. In this case, approval by the Principal is required. The Manufacturer/Supplier shall ensure that the maximum deflection (in all directions) of the flexible coupling as recommended by the flexible coupling manufacturer will not be exceeded.

2.6 BOILER MOUNTINGS

2.6.1 Safety valves

The safety valve(s) at the superheater outlet shall always open before and close after the safety valve(s) on the boiler drum open and close respectively.

The superheater safety valves(s) shall be of such capacity that the superheater cannot be overheated when the boiler drum safety valve(s) are discharging, even under the condition that the superheater outlet is closed when the boiler is being fired at MCR on manual firing control.

The set pressures of boiler drum and superheater safety valves shall take into account the pressure drop between the drum and the superheater outlet at maximum steam flow, plus an additional pressure drop allowance for long term fouling of the superheater.

The rating and setting of safety valves shall be in accordance with the ASME I.

The safety valves shall be of the direct spring-loaded type with springs exposed to the open air, i.e. with open bonnets. They shall be provided with a lifting gear.

NOTE: Air assisted safety valves with triple steam pressure sensors are also acceptable in special cases after approval by the Principal.

All safety valves shall have flanged connections. They shall be adequate for the requirements of the service but shall have inlet and outlet ratings of at least ANS class 300 RF and ANS class 150 RF respectively. Welded connections are not allowed.

Vertical outlets, at least 2000 mm high, shall be provided for safety valves. They shall discharge to a safe location. Outlets shall have safe drainage facilities which shall prevent the accumulation of water.

All safety valve outlets shall be adequately supported to take care of the reaction forces generated while the safety valves are discharging. For noise limitations applicable to safety valves, see (2.11).

2.6.2 Water level gauges

At least two direct-reading level gauges, one installed at each end of the drum, shall be provided. The installation shall comply with the requirements of the boiler code. Where these codes permit the use of alternative types of water level gauge to those in which the water level is observed directly, such application of alternative types shall be subject to the approval of the Principal.

Water level shall be easily visible from the operating platform either by use of a drum gauge image transmission or by a remote level indicator.

2.6.3 Main steam and water valves

The feed water stop and check valves shall be close to the economizer inlet whereas the steam stop and check valves shall be close to the superheater outlet.

2.6.4 Blowdown systems

There shall be facilities for continuous blowdown from the steam drum and for intermittent blowdown from the bottom drum and/or bottom headers, these blowdown lines being connected to a common blowdown vessel.

The continuous blowdown system shall be designed for the maximum continuous blowdown specified on the requisition. At this rate there shall be no interference with the normal water circulation in the boiler or drum level control, or any other adverse effects.

The intermittent system from the bottom drum and/or bottom headers shall ensure that the boiler can be kept free of sludge during operation.

In addition, a start-up blowdown from the steam drum may be specified by the Manufacturer/Supplier if considered necessary for limiting to an acceptable level the water volume surge in the steam drum during boiler start-up. There shall be no water carry-over into the superheater. A start-up blowdown shall have its own blowdown line to the blowdown vessel.

Each system shall have two valves in series, one block valve located at the drum or header and one special blowdown valve located at ground level. These valves shall have a mechanical position indicator and be fitted with a device for locking the blowdown valves in position. For noise limitations, see (2.11).

2.6.5 Start-up vent

Unless otherwise stated, a start-up vent with silencer system with two valves shall be provided to ensure adequate steam flow through the superheater during start-up and when steam is not being delivered from the boiler. The silencer shall have safe drainage facilities which shall prevent accumulation or freezing of water.

For noise limitations applicable to this vent, see (2.11).

2.6.6 Boiler water and steam sampling

Sampling of boiler water and steam shall be in accordance with ASTM D3370 and ASTM D1066 respectively. Nozzles, valves, pipes, fittings and coolers suitable for these sampling methods shall be provided. The piping material for the steam sampling line shall be ASTM A312 grade TP316 and be self-draining to avoid the risk of choride stress corrosion cracking. The piping material for the water sampling line upstream of the isolating valve closest to the drum, and the material of this isolating valve, shall be carbon steel to avoid chloride stress corrosion cracking.

2.7 MATERIALS, FABRICATION AND STRUCTURES

The boiler installation shall be shop-fabricated to the maximum possible extent and shall be transported to site as one complete unit, or as a number of large sub-assemblies ready for, and requiring the minimum of, site assembly.

The extent of shop fabrication shall be clearly specified by the Manufacturer/Supplier and shall be agreed upon between the Manufacturer/Supplier and Principal.

2.7.1 Tubes and pipework

All tubing and piping, flanges and fittings which are not covered by the codes in (2.1) shall comply with the requirements of DEP 31.38.01.10-Gen., DEP 31.38.01.11-Gen. and DEP 31.38.01.12-Gen.

Electric resistance welded (ERW) tubing or piping is acceptable for tubing or piping subject to pressures up to 45 bar (abs), up to a maximum of 100 mm nominal size, and up to a maximum wall thickness of 5 mm provided that it complies with DEP 30.10.02.11-Gen. The use of ERW tubing or piping for higher pressures shall only be permitted after approval by the Principal. In all other cases, seamless tubes or piping is required.

Attention is drawn to the proper drainage/blow drying facilities which may be required to protect against corrosion during shut-down periods. The Manufacturer/Supplier shall state clearly any special provisions required.

Pipe and tube as well as welding return bends shall be selected for the service requirements and in accordance with ISO, ASTM or British Standards or equivalent. The type and material specifications of the tubing and piping shall be stated on the requisition by the Manufacturer/Supplier.

Tube and pipework shall be fabricated in accordance with DEP 31.24.49.31-Gen.

Extended surfaces shall be mechanically rigid and fully welded to tube surfaces. Minimum acceptable fin thickness and maximum number of fins are 1.25 mm and 236/m respectively. A straight tube or pipe shall not be composed of two separate butt-welded parts, unless approved by the Principal. If a butt weld has to be made in the exposed straight length of tubes/pipes, it should not be located near the zone where heat flux will be maximum.

Where boiler, economiser and superheater tubes are bent, the resulting thickness of the tubes at the thinnest part shall be not less than the design value required according to the strength calculation with the corrosion allowance added thereto.

Bending of tubes/pipes shall be in accordance with with DEP 31.38.01.31-Gen.

2.7.2 Welding

Joints shall be made by welding unless explicitly specified otherwise.

All tube ends and pipework shall be suitably prepared for welding where welding is required.

The welding of all parts shall comply with the boiler code as a minimum requirement but also meet any additional requirements of DEP 30.10.60.18-Gen. (e.g. post weld heat treatment of 1¼Cr-½Mo tubes is required).

For welding details not available in the selected code as per (2.1), the instructions of DEP 31.24.49.31-Gen. shall be followed.

Set-in nozzles in wall thickness ≥ 50 mm may be used only for C and CMn steels, and then only if design, materials and welding procedures are such that it can be demonstrated by experience that restraint cracking does not occur. Where this is not possible, forged, saddle-type nozzles shall be used.

Set-on nozzles on plate material shall be used only by prior agreement of the Principal, and in that case the following requirements shall apply:

- Plate material shall meet ASTM A770-S3 (minimum reduction of area of 35%) or German specification SEL 096 Cl. 3.

- a 100% ultrasonic examination shall be carried out on a 100 mm wide band around the nozzle opening before attachment of the nozzle. Acceptance criteria shall be in accordance with BS 5996 L4.

Set-on nozzles are allowed on forgings.

For both set-in and set-on types, the fillet of the attachment weld shall blend smoothly with both vessel and nozzle wall without any notch, sharp corner or undercut.

All inside edges of nozzles and connections, whether flush or extended, shall be rounded off to a minimum radius of 3 mm.

Socket-welded, single fillet-welded, expanded, brazed or screwed connections shall not be used.

All welding shall be done by qualified welders. Qualification tests for welders and welding procedures shall comply with ASME IX or other code stated by the Principal.

Welding materials shall be in accordance with the current list of approved welding consumables published by Lloyd's Register of Shipping, Controlas or equivalent.

2.7.3 Steel structures

Supporting steel structures, platforms, stairs, ladders and railings shall be in accordance with DEP 34.00.01.30-Gen. and DEP 34.28.00.31-Gen. The preferred handrail design is shown on Standard Drawing S 28.006. The steel structure design shall take into account the support requirements for all hydrostatic testing (including during manufacture) as well as for transport and erection.

Further to the requirements of the above specifications, stairs and platforms shall provide easy access to all valves, gauges, instrument process connections, observation points and access doors, and for all other operational purposes. Ladders may only be used for creating extra means of escape. All stairs, platforms and walkways shall be adequately safeguarded with handrailing and toe plates.

All main platforms shall be provided with an emergency means of escape leading down to ground level (i.e. in addition to normal access).

2.7.4 Insulation and refractories

For TEG temperatures up to 550 °C, a bare steel surface (of appropriate grade) with external insulation is preferred. However, the possibility for using internal insulation, in the form of ceramic fibre protected on the flue gas side by stainless steel sheet cladding, is not excluded. This may offer advantages where the casing requires protection against rapid expansion during start-up or where construction of the casing may be profitably simplified using the internal sheeting to create a smooth profile for optimising the TEG flow pattern. However, if the Manufacturer/Supplier chooses to use internal rather than external insulation, a justification for making this choice shall be provided.

For TEG temperatures higher than 550 °C, the Manufacturer/Supplier shall apply internal insulation. Up to a flue gas temperature of 850 °C (i.e. the maximum limit for applying uncooled walls), this internal insulation should be of the type comprising ceramic fibre protected by stainless steel sheet cladding. The type of stainless steel shall be selected on the basis of the peak flue gas temperature predicted for the zone in which it is applied. The cladding plates shall overlap in the direction of gas flow. It should be noted that the susceptibility of plates to thermal deformation increases with temperature and plate size. The Manufacturer/Supplier shall take this into account in the selection of cladding plate dimensions. Particular attention shall be given to the firing zone, where high/differential temperatures may develop. No fixed rules are given for maximum plate size but, as a guide, a plate of 1 m^2 may be regarded as large for application in the combustion zone. Support of the cladding sheets also requires careful design; the Manufacturer/Supplier shall ensure that the steel sheeting is supported firmly on both surfaces such that TEG pressure fluctuations or vibrations will not cause the sheet to move or work loose and compress the underlying ceramic fibre. Particular attention shall be given to the duct floor, which shall be sufficiently strong to bear the weight of maintenance personnel. The thickness of sheet and pitch of the anchors shall be so chosen to meet this requirement.

The selection and application of ceramic fibre insulation shall conform with with the latest practice in respect of health, safety and environment. Specifically, reference is made to Shell document MF 88-0825 and the Code of Practice of the European Ceramic Fibres Industry Association (ECFIA).

Insulating refractory concrete or bricks may be applied for uncooled surfaces where the stainless steel clad ceramic fibre type internal insulation would not be suitable, or for particular applications such as burners. When specifying the refractory type, due account shall be taken of the rate of temperature increase of the TEG during start-up. Insulating refractory concrete and refractory bricks shall be in accordance with DEP 64.24.32.30-Gen. and with DEP 44.24.90.31-Gen. respectively. The Manufacturer/Supplier shall give in his tender full, detailed specifications of the refractory and insulation materials to be used, together with any deviations from the above standards.

Insulation shall be in accordance with DEP 30.46.00.31-Gen.

External insulation shall be covered with sheeting installed in such a way that the insulation remains perfectly dry and free from ingress of water and has sufficient allowance for expansion.

Manholes, access doors, etc. shall have their own separate insulation or refractory so that they can be opened without damage to the insulation or refractory.

2.8 PRESERVATION AND INITIAL PREPARATION

All painting, both at works and on site, shall be in accordance with DEP 30.48.00.31-Gen. Any case not covered by this specification shall be discussed with the Principal.

Galvanizing shall be in accordance with ASTM A123 or BS 729.

NOTE: Galvanizing is not allowed on the water and steam side of tubes or piping.

The superheater shall be freed from millscale before departure from manufacturer's works because, during commissioning, it will be steam blown only.

All boxes, vessels, tubes and internal connecting lines shall be cleaned and thoroughly dried out prior to departure from the works. At that time all openings shall be closed to prevent foreign matter from entering during transport or erection.

2.9 SPECIAL TOOLS

All special tools required for maintenance and operation, such as tube expanders, special wrenches, etc., shall be supplied with the installation.

2.10 CHEMICAL DOSING INSTALLATION

An installation suitable for dosing the necessary chemicals for the boiler shall be provided.

This may comprise, for example:

- a dosing installation for continuous alkalinity control by means of NaOH
- a dosing installation for phosphates
- dosing installations for hydrazine/sulphite/morpholine, or other chemicals.

Each dosing installation shall be provided with a dosing pump complete with installed spare. The stroke of the pumps shall be adjustable during operation and standstill. Dosing pumps shall be in accordance with DEP 31.29.12.30-Gen.

Chemicals should be injected at the suction side of the feed water pump except where boiler feed water is used for desuperheating, in which case chemicals shall be injected downstream of the desuperheating water take-off.

The above installations shall be complete with lines, valves, pumps, vessels, mixers, mountings, heaters, if necessary, and arrangements to avoid health and safety hazards.

2.11 NOISE LIMITATIONS

2.11.1 General

EEMUA 140 shall apply with regard to definitions, notations, measuring equipment and procedures, test reporting, calculation methods and procedures.

2.11.2 Noise limits

The maximum allowable sound pressure level shall not exceed 85 dB(A) in the work area, i.e. any position accessible to personnel at a distance not less than 1 m from the equipment surfaces.

The above limit may be adapted by limits given in the noise limitation data sheet, DEP 31.10.00.94-Gen. which forms part of the requisition.

The requirements apply in the absence of reverberation and background noise from equipment other than the boiler installation, for all operating conditions between minimum load and MCR.

If the equipment produces impulsive and/or narrow band noise, the noise limits shall be 5 dB(A) lower than the values stated above or in the requisition.

For safety valves which discharge under emergency conditions only, the above limitations are relaxed such that the noise level in the work area shall never be greater than 115 dB(A) when they are discharging.

For start-up, shut-down and testing situations which are to be considered as normal operation, a relaxation is accepted. In such situations, the equivalent sound pressure level over an 8 hour period shall not exceed 85 dB(A) in the work area. However, the maximum level shall not exceed 95 dB(A).

2.11.3 Noise abatement

Excessive equipment noise should be eliminated by low noise design. Where other noise control measures, such as acoustic enclosures are required, they shall not in any case obstruct operational or routine maintenance activities. Where noise hoods are proposed, prior approval of the Principal shall be obtained regarding construction, materials and safety requirements.

Acoustic insulation of pipes, valves and flanges shall be in accordance with DEP 31.46.00.31-Gen.

2.11.4 Information to be submitted with the tender

The Manufacturer/Supplier shall submit the sound power levels and sound pressure levels of the equipment, together with any other relevant information as requested in the equipment noise limitation sheet DEP 31.10.00.94-Gen., in the silencer data/requisition sheet DEP 31.10.00.95-Gen. and acoustic enclosure data/requisition sheet DEP 31.10.00.96-Gen.

3. INSTRUMENTATION AND CONTROL

3.1 GENERAL

Amended per Circular 20/99

The piping and instrumentation diagram shall include all controls and instrumentation for the proper operation and safety of the boiler under all operating situations. It shall also indicate the terminal points for the scope of supply. These shall be prepared in accordance with DEP 32.10.03.10-Gen.

If indicated by the Principal, the design shall be suitable for local start-up and shutdown of the boiler. It shall be possible to monitor the status of operation of the boiler from the main control room. If supplementary firing is required, automatic burner start-up facilities shall be included.

If safeguarding of the control system, including instrumentation, is to be included in the Manufacturer/Supplier scope, this shall be specified by the Principal.

The Manufacturer/Supplier shall provide all the necessary mechanical provisions in his equipment for the installation of instruments and controls in accordance with DEP 32.31.09.31-Gen.

3.2 FUNCTIONAL DEFINITION OF INSTRUMENTATION AND CONTROLS

The Manufacturer/Supplier shall submit with his tender, function descriptions of the controls, measurements and safety logic descriptions, to clearly convey their purpose in the proper operation and protection of the boiler. These shall be written in support of the piping and instrumentation diagrams, safety logic diagrams and local panel details that have been prepared (3.1.1 and 3.1.2).

The design shall satisfy the national requirements applicable in the country of destination.

3.3 DESIGN STANDARDS FOR ENGINEERING AND INSTALLATION

Amended per Circular 43/96

The location of measuring points, controls, control valves, transmitters etc., shall be easily accessible for operation and maintenance (see 2.7.3 for stairs/platform provisions).

Electronic instruments shall be applied for operational measurements, controls and safety as far as possible. Pneumatic/electric actuators shall be used for control valves and dampers. Hydraulic valve actuation shall be considered only if it is essential.

The control system design shall provide stable control over the anticipated load range the boiler is expected to handle. The control valves shall be properly sized to meet this requirement.

Applicable standards for design and installation are:

Amended per Circular 20/99

Instruments for measurement and control	DEP 32.31.00.32-Gen.
Instrumentation documents and drawings	DEP 32.31.00.34-Gen.
Instrumentation for equipment packages	DEP 32.31.09.31-Gen.
Control valves - selection, sizing and specification	DEP 32.36.01.17-Gen.
Instrument impulse lines	DEP 32.37.10.11-Gen.
Instrument signal lines	DEP 32.37.20.10-Gen.

Instrument air lines	DEP 32.37.51.11-Gen.
Control valves	In-3-1
Field inspection and testing of instruments and instrument systems	DEP 62.10.08.11-Gen.
Factory inspection and testing of instruments and instrument systems	DEP 62.10.09.11-Gen.
Instrumentation symbols and identification on process engineering flow schemes	DEP 32.10.03.10-Gen.

4. ELECTRICAL INSTALLATIONS

Electrical installations and lighting shall comply with DEP 33.64.10.10-Gen.

5. INSPECTION BY PRINCIPAL

The Principal shall indicate if he (or nominee) wishes to attend during manufacture and/or testing, in which case the scope of his involvement shall be advised to the Manufacturer/Supplier.

The Manufacturer/Supplier shall submit materials test certificates in accordance with ISO 10474, type 3.1.B for boiler pressure retaining parts.

6. ERECTION, CHEMICAL CLEANING, START-UP AND PERFORMANCE TESTING

6.1 MECHANICAL ERECTION

Mechanical erection shall include any applicable tests and services such as cleaning, hydrostatic testing, chemical cleaning, drying out, setting of safety valves and the like, as may be required to prepare for start-up. Mechanical erection shall be carried out by the Manufacturer/Supplier, or under his supervision, as specified on the requisition.

The installation of rotating equipment shall be in accordance with DEP 31.29.00.10-Gen.

Where applicable, the refractories shall be kept free from freezing before initial start-up.

The boiler and ducting shall be mounted in such a way that free expansion is possible so that no undue stresses are caused to adjoining structures, equipment and foundations.

After completion of erection but before the drum internals are installed, all extraneous material shall be removed from the boiler, superheater and economizer.

The Manufacturer/Supplier shall specify whether or not the waterside surfaces shall be acid cleaned prior to start-up but this shall be subject to approval of the Principal. If acid cleaning is required, this shall be carried out at this stage and in accordance with DEP 70.10.80.11-Gen. All equipment necessary for the pre-start-up cleaning, such as pump,tanks, heaters, valves, piping and chemicals shall be supplied by the Contractor.

Whether acid cleaning is required or not, suitable connections on the boiler such as nozzles etc.,shall be provided for acid cleaning at a future date.

6.2 START-UP

After completion of mechanical erection, pre-start-up functionality tests of the control and safeguarding shall be carried out. Unless otherwise specified, these tests shall be carried out by the Principal under supervision of the Manufacturer/Supplier.

The boiler will be put into operation by the Principal under supervision of and, if required, with the assistance of the Manufacturer/Supplier. This shall include the refractory dry-out where applicable, and the alkali boil-out for which DEP 70.10.80.11-Gen.shall apply; the chemicals for the boil-out shall be supplied by the Manufacturer/Supplier.

The Manufacturer/Supplier shall instruct the Principal's staff in the correct methods of start-up, operation, shut-down, emergency procedure, cleaning and maintenance.

6.3 PERFORMANCE/ACCEPTANCE TESTS

Amended per Circular 43/96

Performance and acceptance testing shall start only after the installation has been operating satisfactorily at MCR for a continuous period of five days unless the Principal stipulates a lower load and/or period to suit conditions prevailing at the time.

Unless specified otherwise, the performance/acceptance tests shall be carried out by the Principal in the presence of the Manufacturer/Supplier who shall give assistance, if requested, by the Principal. In the event of a prolonged delay between start-up and the ability to carry out one or more of the tests (eg. due to non availability of a specified fuel), the performance guarantees may be affected and this shall be subject to agreement between the Principal and the Manufacturer/Supplier.

The tests shall be performed using the specified fuels and be designed to verify the performance guarantees made by the Manufacture/Supplier. The principle parameters examined are, but not necessarily limited to:

- capacity
- export steam purity
- export steam temperature/pressure
- combustion performance

- thermal efficiency
- general mechanical integrity (eg. free expansion, damper operation)
- noise emission
- automatic control and load response

The performance tests shall be carried out at the following conditions:

-	at peak boiler load	-for 2 hours
-	at MCR of boiler (where applicable, with turbine load which gives maximum firing load on supplementary burners).	-for 8 hours
-	at minimum boiler load (where applicable, with turbine load which gives minimum firing load on supplementary burners).	-for 8 hours
-	at any additional operating condition as specified in the requisition.	

Unless otherwise specified, the plant instruments may be used for the performance tests after agreement has been reached between the Principal and the Manufacturer/Supplier on the calibration and accuracy of the plant instruments.

If it is specified that the plant instruments may not be used for the performance tests, or if the Manufacturer/Supplier does not agree to the use of plant instruments, the Manufacturer/Supplier shall provide the calibrated test instruments and apparatus for the tests.

Methods for the determination of steam purity shall be agreed between Principal and Manufacturer/Supplier.

Efficiency tests and calculations shall be carried out according to the 'Losses Method' described in the ASME Performance Test Code PTC 4.4.

Flow metering shall be in accordance with DEP 32.31.00.32-Gen.

Where the Manufacturer/Supplier does not provide the instrumentation and control system, the boiler supplier shall remain responsible for the boiler performance guarantees, on the basis that the boiler supplier agrees with the principles of the instrumentation and control system which will be applied.

7. DOCUMENTATION

7.1 GENERAL

The English language shall be used throughout unless otherwise specified, except that descriptions on drawings may be in other languages, provided that English translations are given.

The Manufacturer/Supplier shall provide all drawings, design details, operation and maintenance manuals, and other information necessary for the design assessment, erection, operation and maintenance of the installation. All information, especially the manuals for operation and maintenance, shall be clear and not open to misinterpretation and shall apply specifically to the installation supplied.

7.2 DATA/REQUISITION SHEETS AND DOCUMENTATION REQUIRED AT TENDERING STAGE

For the exchange of information between the Principal and the Manufacturer/Supplier, use shall be made of data/requisition DEP 30.75.10.94-Gen. (sheets 1 to 9).

7.2.1 Data/requisition sheets 1, 2 and 3

Sheets 1, 2 and 3 shall be completed by the Principal.

These sheets describe, in conjunction with this specification, the extent of the project and contain data provided by the Principal.

Battery limit conditions for all items mentioned under the heading 'Utilities' will normally be indicated on the flow scheme and on the proposed control schemes.

Where necessary, the Principal will also give additional information on existing equipment, e.g. blowdown line system, vents and drains, chemical dosing system and feed pumps.

7.2.2 Data/requisition sheets 4 to 9

Sheets 4 through 9 shall be completed by the prospective Manufacturer/Supplier at the tendering stage.

It is accepted that, at this stage, certain data requested on the data/requisition sheets will not have been finalised. However, rather than giving no information in such cases, the Manufacturer/Supplier shall give anticipated data so that a clear appreciation can be made of the equipment offered. This is necessary for the Principal to make a pre-selection of the tenders. The data may be updated later by the Manufacturer/Supplier prior to the final selection stage.

The following drawings and information shall be submitted with the completed data/requisition sheets:

(a) Drawings of:

- dimensioned general arrangement, front and side elevations and plan of complete installation showing location of turbine, boiler, ducting including guide vanes and expansion joints, damper, isolator, burners, galleries and stairs, ladders and stacks.
- dimensioned front and side sectional elevations and sectional plan of boiler, showing drum, casing, combustion chamber, burners, insulation, access and observation ports and all tube banks. The combustion chamber in particular must be fully dimensioned including burner centre lines.

(b) Description of:

- extent of shop fabrication
- general description of installation
- boiler, indicating site fabrication required
- casing
- ducting, including expansion joints
- refractory, insulation, as well as anchors and sheeting
- burners
- damper and isolator
- desuperheater
- purging, sealing and cooling air system
- circulating pump and drive
- mountings, valves and fittings, including safety valves
- control schemes and description of all controls, especially combustion control scheme and start-up logic.

(c) Graphs showing:

- TEG and flue gas, water and steam enthalpies and temperatures in each boiler tube bank at MCR and minimum boiler load.
- controlled and uncontrolled superheated steam temperature and turbine load with and without burner firing.
- steam mass flow and turbine load with and without burner firing.
- burner fuel consumption, stack oxygen content and and turbine load.
- other graphs if specified on data/requisition sheet 3.

(d) The capital costs of:

- boiler including furnace if applicable, superheater, economizer, drum
- structural steelwork
- fuel burning equipment
- boiler inlet and flue gas ducting, stacks and duct per metre run
- pipework
- mountings, valves and fittings, including safety valves
- refractories/insulation and sheeting
- instrumentation
- miscellaneous items
- erection/supervision of erection
- start-up/performance testing.

(e) Period of delivery:

- time from award of contract to arrival f.o.b. at port
- time from arrival at site to acceptance
- estimated manhours and minimum time needed for erection.

(f) Lists of:

- reference gas turbine heat recovery steam generators of the same type, including location, capacity, superheated steam pressure and temperature, fuels fired, feed water quality if possible, and gas turbine type and fuels fired
- any deviations from the requirements of this specification
- sub-suppliers
- all instruments needed and their location (local, local panel, control room)
- major shipping weights and dimensions
- provisions made for safety and emergencies.

7.2.3 Revised data/requisition sheets 4 to 9

A revision of data sheets 4 through 9 shall be submitted by selected suppliers for the final evaluation and selection by the Principal. This revision shall reflect any changes arising from bid clarification discussions with the Principal and firm data previously submitted as anticipated data (see 7.2.3).

The following information shall be submitted together with the revision:

- details of the combustion chamber wall construction, showing tubes and if applicable insulation anchors and sheeting
- burner details
- burner characteristics
- flame patterns
- dimensioned details of drums and internals
- boiler and ducting support and expansion details
- tube bank support details
- details of damper, isolator and expansion joint constructions and materials
- diagram showing superheater materials as well as corresponding metal temperatures at MCR and peak load, with and without steam temperature control
- circulating pump characteristics
- forced draught fan characteristics (where applicable)
- list of drives, showing type, manufacturer, duty, delivered power, couplings and gear boxes
- list of vents, stop and check valves, showing sizes, capacities and manufacturers
- list of refractories and insulation materials, showing type, location, protection, fastening and surface temperature
- dimensions and mass details for shipping and erection purposes.

7.3 DOCUMENTATION AND INFORMATION REQUIRED AFTER CONTRACT AWARD

The following shall be submitted after the contract has been awarded:

- detailed calculations on tube dimensions and materials for drum and major heat transfer equipment
- all necessary information on mass, moments, location of foundation bolts, etc., for the design of the foundation. Manufacturer/Supplier shall approve the foundation drawings
- mounting and foundations of pumps and drives
- resistance and temperature characteristics on the gas side over the whole installation
- details of all pumps, fans (with characteristic curves), drives and instruments

NOTE: For electric drives, the Manufacturer/Supplier will receive requisition sheets for electric motors, partly filled in by the Principal.

- detailed calculations on tube bank vortex shedding frequencies, tube natural frequencies and boiler casing acoustic frequencies.
- list of manufacturers of all major equipment, tubes and tube fittings
- list of all spare parts, including list of initial spare parts necessary for start-up and first year of operation, with detailed prices and time of delivery. Also, a spare parts interchangeability record (SPIR).
- list of all tools necessary for operation, maintenance, inspection and cleaning insofar as not normally found in a refinery workshop
- the mass of:
    - boiler empty
    - boiler full (hydraulic test conditions)
    - boiler full (working conditions)
    - circulating pumps and drives
    - fans and drives
    - ducting, stacks and isolator
    - damper and drive
- six copies of the operation and maintenance manuals.

8. REFERENCES

Amended per Circular 43/96

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 DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Metallic materials - Selected standards	DEP 30.10.02.11-Gen.
Welding of metals	DEP 30.10.60.18-Gen.
Thermal insulation for hot services	DEP 30.46.00.31-Gen.
Painting and coating for new construction projects	DEP 30.48.00.31-Gen.
Noise control	DEP 31.10.00.31-Gen.
Shop fabrication of heater piping	DEP 31.24.49.31-Gen.
Installation of rotating equipment	DEP 31.29.00.10-Gen.
Pump selection, testing and installation	DEP 31.29.02.11-Gen.
Centrifugal pumps	DEP 31.29.02.30-Gen.
Reciprocating positive displacement pumps and metering pumps	DEP 31.29.12.30-Gen.
Centrifugal fans	DEP 31.29.47.30-Gen.
Steam turbines - Selection, testing and installation	DEP 31.29.60.10-Gen.
General-purpose steam turbines	DEP 31.29.60.30-Gen.
Piping - General requirements	DEP 31.38.01.11-Gen.
Piping classes	DEP 31.38.01.12-Gen.
Shop and field fabrication of steel piping	DEP 31.38.01.31-Gen.
Acoustic insulation for pipes, valves and flanges	DEP 31.46.00.31-Gen.

Amended per Circular 20/99

Instrumentation symbols and identification on process engineering flow schemes	DEP 32.10.03.10-Gen.
Instruments for measurement and control	DEP 32.31.00.32-Gen.
Instrumentation documents and drawings	DEP 32.31.00.34-Gen.
Instrumentation for packaged units	DEP 32.31.09.31-Gen.
Control valves - selection, sizing and specification	DEP 32.36.01.17-Gen.
Instrument impulse lines	DEP 32.37.10.11-Gen.

Instrument signal lines	DEP 32.37.20.10-Gen.
Instrument air lines	DEP 32.37.51.11-Gen.
Electrical engineering guidelines	DEP 33.64.10.10-Gen.
Electric motors	DEP 33.66.05.31-Gen.
Minimum requirements for structural design and engineering	DEP 34.00.01.30-Gen.
Steel stacks	DEP 34.24.26.31-Gen.
Steel structures	DEP 34.28.00.31-Gen.
Refractory bricks and shapes	DEP 44.24.90.31-Gen.
Field inspection and testing of instruments and instrument systems and instrument systems	DEP 62.10.08.11-Gen.
Factory inspection and testing of instruments and instrument systems	DEP 62.10.09.11-Gen.
Insulating and dense refractory concrete linings	DEP 64.24.32.30-Gen.
Cleaning of equipment	DEP 70.10.80.11-Gen.
Control valves	In-3-1
MF Report "Man made mineral fibres"	MF 88-0825

REQUISITIONS

NOTE: The latest revisions of data/requisition sheets are identified in DEP binder 30.10.01.10-Gen.

Data/requisition sheets for gas turbine waste heat boilers	DEP 30.75.10.94-Gen.
Data/requisition sheet for equipment noise limitation	DEP 31.10.00.94-Gen.
Data/requisition sheet for vent/blowdown/air flow/ in-line silencers	DEP 31.10.00.95-Gen.
Data/requisition sheet for rotating equipment acoustic enclosures	DEP 31.10.00.96-Gen.

STANDARD DRAWINGS	Drawing No.

NOTE: The latest revisions of Standard Drawings are identified in DEP 00.00.06.06-Gen.

Flanged connection for flue duct	S 24.301
Handrailing, type 'A'	S 28.006

AMERICAN STANDARDS

ASME Boiler and Pressure Vessel Code	Section I Power Boilers

	Section IX - Welding and Brazing Qualifications
ASME Performance Test Code-Gas Turbine Heat Recovery Steam-generating units	PTC 4.4

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

High-Speed, Special Purpose Gear Units for Refinery Services	API Std 613

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

High-Speed Helical and Herringbone Gear Units	AGMA 421.06

Issued by:
American Gear Manufacturers Association
1901 North Fort Myer Drive, Suite 1000
Arlington, Virginia 22209
USA.

Zinc (Hot-Galvanized) Coatings on Products Fabricated from Rolled, Pressed and Forged Steel Shapes, Plates, Bars and Strips	ASTM A123
Seamless and welded austenitic stainless steel pipes	ASTM A312
Through-thickness tension testing of steel plates for special applications	ASTM A770
Sampling Steam	ASTM D1066
Practices for Sampling Water	ASTM D3370

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

Factory-made Wrought Steel Butt Welding Fittings	ANSI B16.9
Wrought Steel Butt Welding Short Radius Elbows and Returns	ANSI B16.28
Power piping	ANSI/ASME B31.1

Issued by:
American National Standards Institute
1430 Broadway, New York
NY 10018
USA.

BRITISH STANDARDS

Hot-dip galvanized coatings on iron and steel articles	BS 729
Water-Tube Steam Generating Plant	BS 1113
Steel butt-welding pipe fittings for the petroleum industry	BS 1640
Ultrasonic testing and specifying quality grades of ferritic steel plate	BS 5996

Issued by:
British Standards Institution
2 Park Street
London W1A 2BS
England
United Kingdom

Noise Procedure Specification	EEMUA 140

Issued by:
The Engineering and Equipment Users Association
14 -15 Belgrave Square
London SW1X 8PS
England
United Kingdom.

INTERNATIONAL STANDARDS

Steel and steel products - Inspection documents	ISO 10474

Issued by:
Central Secretariat of International
Organisation for Standarization (ISO)
1, Rue de Varembé
CH-1211 Geneva 20
Switzerland.

APPENDICES

APPENDIX 1 SCOPE OF SUPPLY AND TERMINAL POINTS

A list entitled 'Scope of supply' and a list entitled 'Terminal points', shall be provided by the Principal. These lists refer to the individual requirements of each project. To assist in the compilation of these lists, typical examples are given below.

A sketch may also be found useful in defining the 'Terminal points' (e.g. fuel line terminal points), in which case such a sketch should be attached to the 'Terminal point' list.

SCOPE OF SUPPLY (Typical example)

Gas turbine heat recovery steam generators, each boiler complete with:

1. Instrumentation and control system
2. Superheater
3. Economizer
4. Circulation pumps and 4.1 Steam turbine drive 4.2 Electric motor drive
5. Burners and flame scanners suitable for burning all specified fuels
6. Ignition units for each burner
7. Steel structures
8. Galleries, platforms, stairways, ladders
9. Pipework
10. Mountings, valves and fittings
11. Steel stack
12. All ducting from turbine to stack
13. Damper and isolator
14. Start-up vent
15. Sealing, purging, cooling air system
16. Sealing, cooling water system
17. Steam and water sampling system
18. Foundation bolts
19. Gaskets, welding rods, jointing materials
20. Special tools
21. Refractories and insulation
22. Chemical dosing installation

TERMINAL POINTS (Typical example)

1. Feed water Inlet of the main feed stop valve
2. Main steam Outlet of the superheated steam outlet stop valve
3. Turbine exhaust gas Outlet of turbine exhaust duct Inlet/outlet of the by-pass stack
4. Flue gas In/outlet of the boiler stack
5. Fuels
   Supply line isolation valve and spectacle blind.
6. Drains
   Outlets of drain valves
7. Blowdown
   Outlets of the special blowdown valves
8. Cooling water
   Inlet and outlet flanges of all cooling water consuming parts
9. Steam turbine
   Inlet flange of steam turbine inlet stop valve
   Outlet flange of steam turbine
10. Electrical supply to motors
    Motor terminals (but not including connection of supply cable).

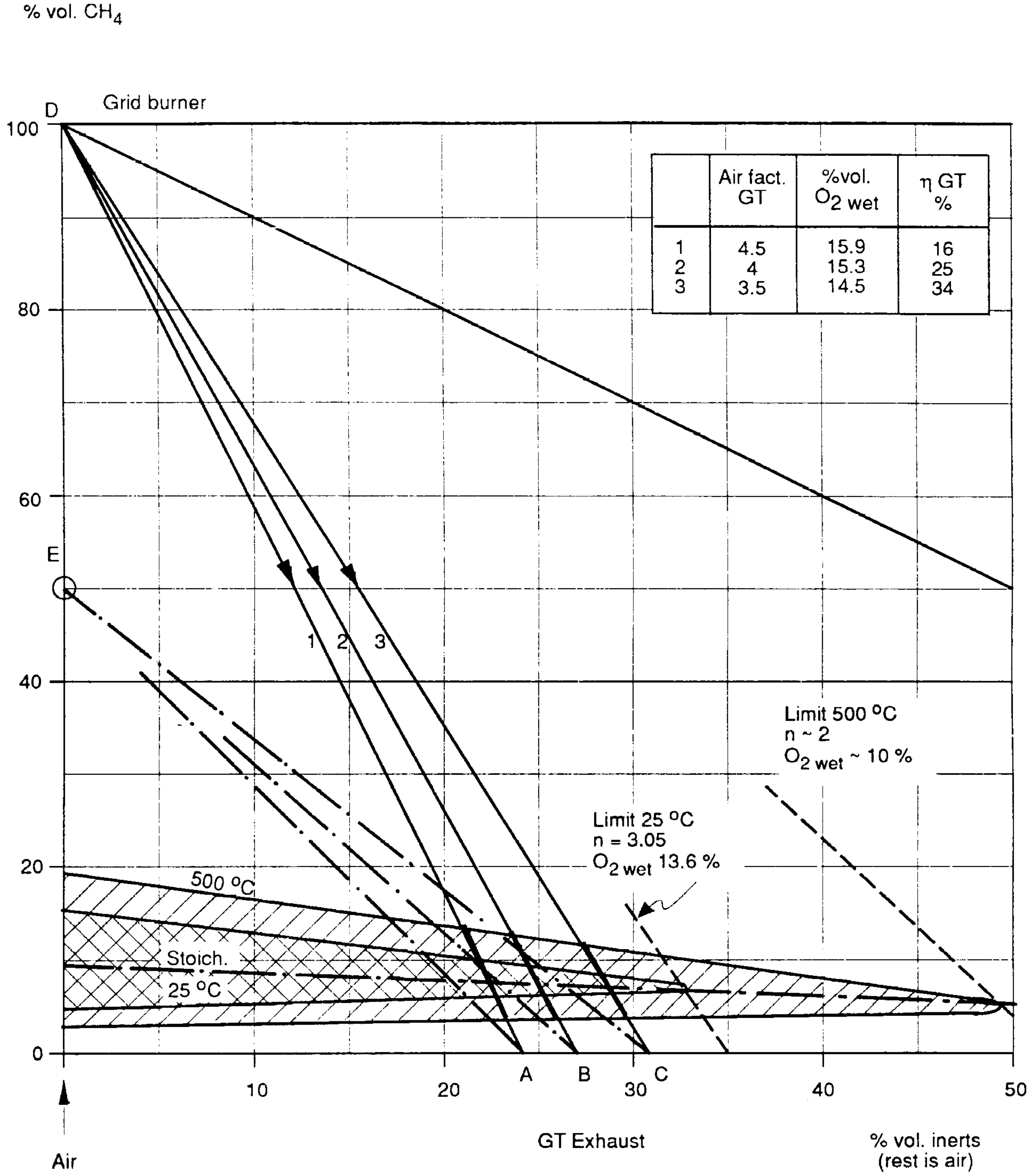
APPENDIX 2 DATA RELATING TO START-UP CRITERIA

TABLE A

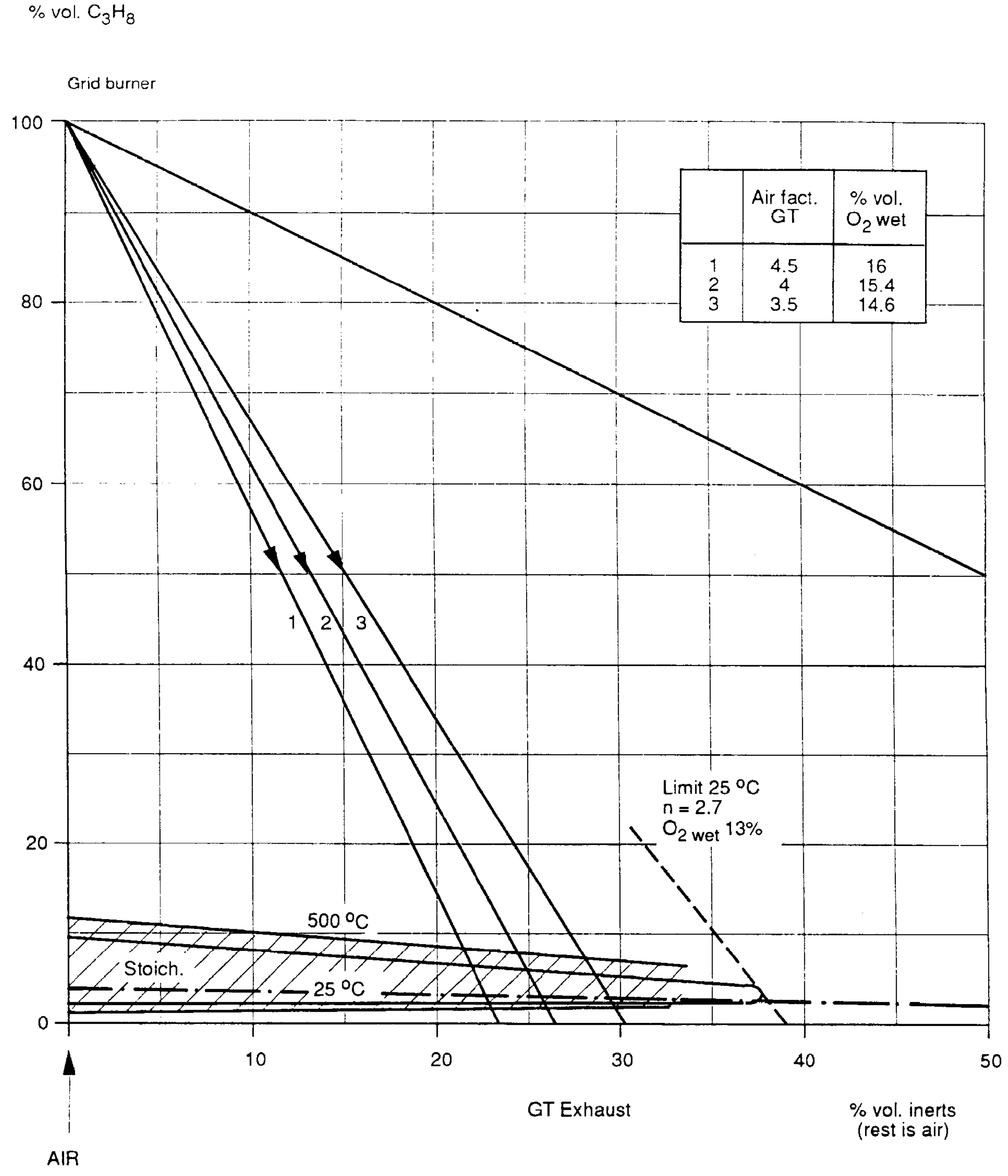
Fuel gas components, stoichiometry and flammability limits at ambient temperature in air.

Component	%-vol. in mixture with air		
	LFL	STOICH	HFL
H_2	4.1	29.53	74
CH_4	5.0	9.48	15
C_2H_2	1.5	7.73	82
C_2H_4	2.6	6.53	34
C_2H_6	3.2	5.65	12.5
C_3H_6	2.0	4.45	11.7
C_3H_8	2.1	4.02	9.5
iC_4H_{10}	1.9	3.12	8.5
nC_4H_{10}	1.6	3.12	8.5
iC_5H_{12}	1.4	2.55	7.6
nC_5H_{12}	1.3	2.55	7.6
CO	12.5	29.53	74
H_2S	4.3	12.25	46
CH_3OH	6.7	12.25	36

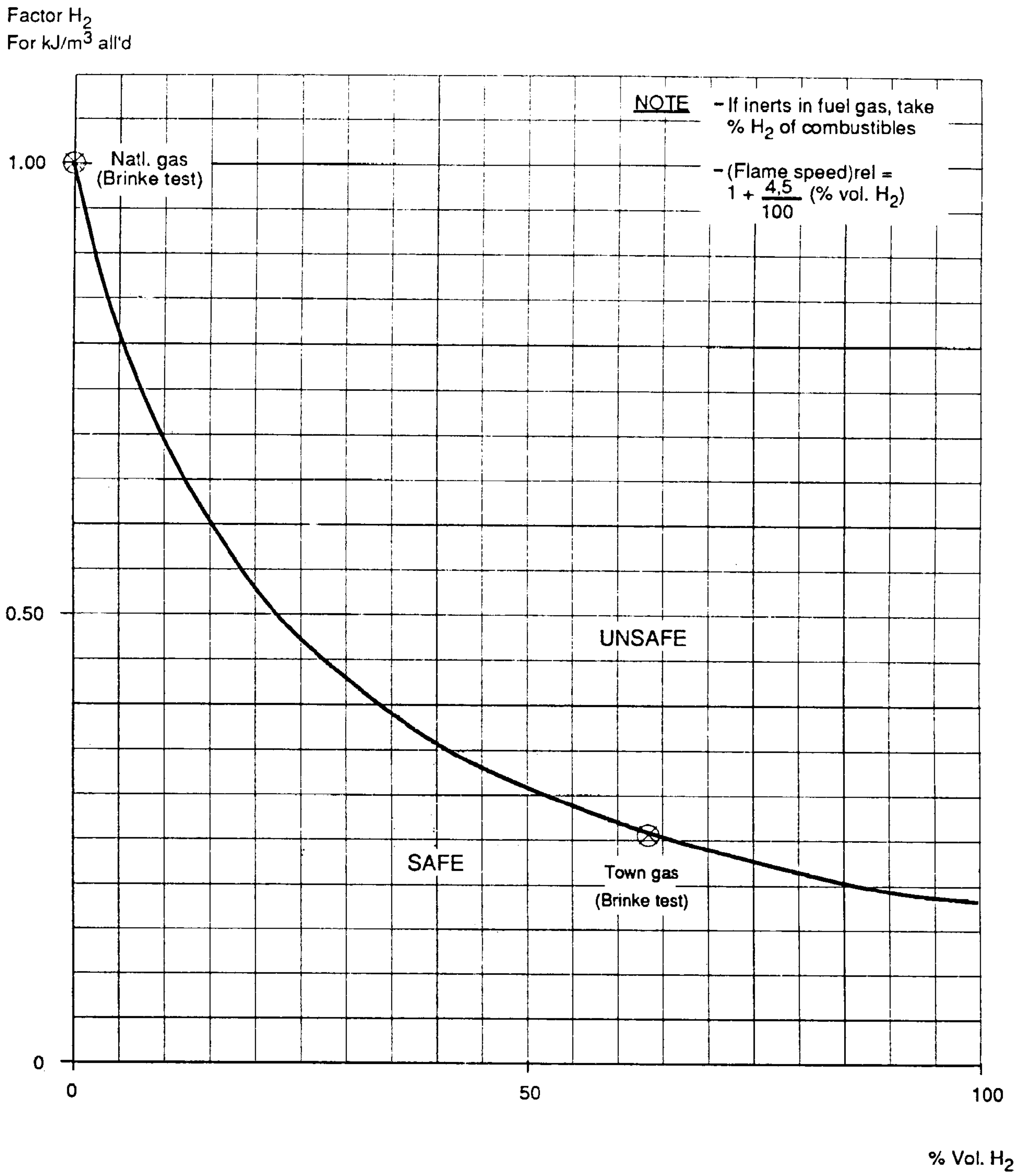
APPENDIX 2 (cont'd) FIGURE 1: CH_4/INERTS/AIR DIAGRAMS



APPENDIX 2 (cont'd) FIGURE 2: CH_3H_8/INERTS/AIR DIAGRAM



APPENDIX 2 (CONT'D) FIGURE 3: (FLAME SPEED) CORRECTION FOR H_2 PRESENCE



APPENDIX 2 (cont'd) FIGURE 4: FACTORY DESIGN PRESS. CASING("ENERGY" CRITERION)