

DEP SPECIFICATION

STEAM, CONDENSATE AND BOILER FEED WATER SYSTEMS

DEP 30.75.10.10-Gen.

February 2012

DESIGN AND ENGINEERING PRACTICE

DEM1



© 2012 Shell Group of companies
All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, published or transmitted, in any form or by any means, without the prior written permission of the copyright owner or Shell Global Solutions International BV.

PREFACE

DEP (Design and Engineering Practice) publications reflect the views, at the time of publication, of Shell Global Solutions International B.V. (Shell GSI) and, in some cases, of other Shell Companies.

These views are based on the experience acquired during involvement with the design, construction, operation and maintenance of processing units and facilities. Where deemed appropriate DEPs are based on, or reference international, regional, national and industry standards.

The objective is to set the standard for good design and engineering practice to be applied by Shell companies in oil and gas production, oil refining, gas handling, gasification, chemical processing, or any other such facility, and thereby to help achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to Shell companies for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual Operating Units to adapt the information set forth in DEPs to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use DEPs, they shall be solely responsible for such use, including the quality of their work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the Principal will typically expect them to follow those design and engineering practices that will achieve at least the same level of integrity as reflected in the DEPs. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the Principal.

The right to obtain and to use DEPs is restricted, and is typically granted by Shell GSI (and in some cases by other Shell Companies) under a Service Agreement or a License Agreement. This right is granted primarily to Shell companies and other companies receiving technical advice and services from Shell GSI or another Shell Company. Consequently, three categories of users of DEPs can be distinguished:

- 1) Operating Units having a Service Agreement with Shell GSI or another Shell Company. The use of DEPs by these Operating Units is subject in all respects to the terms and conditions of the relevant Service Agreement.
- 2) Other parties who are authorised to use DEPs subject to appropriate contractual arrangements (whether as part of a Service Agreement or otherwise).
- 3) Contractors/subcontractors and Manufacturers/Suppliers under a contract with users referred to under 1) or 2) which requires that tenders for projects, materials supplied or - generally - work performed on behalf of the said users comply with the relevant standards.

Subject to any particular terms and conditions as may be set forth in specific agreements with users, Shell GSI disclaims any liability of whatsoever nature for any damage (including injury or death) suffered by any company or person whomsoever as a result of or in connection with the use, application or implementation of any DEP, combination of DEPs or any part thereof, even if it is wholly or partly caused by negligence on the part of Shell GSI or other Shell Company. The benefit of this disclaimer shall inure in all respects to Shell GSI and/or any Shell Company, or companies affiliated to these companies, that may issue DEPs or advise or require the use of DEPs.

Without prejudice to any specific terms in respect of confidentiality under relevant contractual arrangements, DEPs shall not, without the prior written consent of Shell GSI, be disclosed by users to any company or person whomsoever and the DEPs shall be used exclusively for the purpose for which they have been provided to the user. They shall be returned after use, including any copies which shall only be made by users with the express prior written consent of Shell GSI. The copyright of DEPs vests in Shell Group of companies. Users shall arrange for DEPs to be held in safe custody and Shell GSI may at any time require information satisfactory to them in order to ascertain how users implement this requirement.

All administrative queries should be directed to the DEP Administrator in Shell GSI.

TABLE OF CONTENTS

1.	INTRODUCTION	5
1.1	SCOPE.....	5
1.2	DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS	5
1.3	DEFINITIONS	5
1.4	CROSS-REFERENCES	7
1.5	COMMENTS ON THIS DEP	7
1.6	DUAL UNITS.....	7
2.	STEAM GENERATION	8
2.1	GENERAL DESIGN CONSIDERATIONS	8
2.2	BOILERS/STEAM GENERATORS BLOWDOWN.....	9
2.3	CBD/IBD PIPING	9
2.4	CBD/IBD FLASH VESSELS	10
2.5	SPARING PHILOSOPHY	10
2.6	STEAM LOAD SHEDDING.....	10
2.7	PRESTART UP AND OPERATIONAL CLEANING	10
3.	BOILER FEED WATER.....	12
3.1	BOILER FEED WATER QUALITY.....	12
3.2	ATTEMPERATOR WATER QUALITY	12
3.3	CHEMICAL DOSING FACILITIES.....	12
3.4	BOILER FEED WATER MAKEUP AND STORAGE.....	13
3.5	DEMINERALISED WATER QUALITY MEASURING INSTRUMENTS.....	13
3.6	DEMINERALISED WATER TRAINS	14
3.7	CONDENSATE RECOVERY SYSTEM.....	15
3.8	BFW AND CONDENSATE PUMPS.....	16
3.9	CONDENSATE TREATMENT	16
3.10	BOILER WATER TREATMENT	18
3.11	FLOW ACCELERATED CORROSION (FAC)	18
3.12	STEAM, BOILER FEED WATER AND CONDENSATE SAMPLING REQUIREMENTS	18
4.	STEAM HEADERS.....	20
4.1	STEAM DISTRIBUTION HEADERS.....	20
4.2	PRESSURE REDUCING AND DESUPERHEATING STATION	22
4.3	ATOMISING STEAM LINES	23
4.4	DRAINS AND DRIP LEGS.....	23
4.5	STEAM TRAPS.....	24
4.6	CONDENSATE HEADERS.....	25
4.7	THERMAL EXPANSION AND PIPING FLEXIBILITY	27
4.8	PIPE SUPPORTS	27
5.	DEAERATOR DESIGN CONSIDERATIONS.....	28
5.1	DEAERATOR FEED WATER PREHEAT SYSTEMS.....	28
6.	UTILITY BOILER FUEL SYSTEM DESIGN CONSIDERATIONS.....	29
7.	REFERENCES	30

APPENDICES

APPENDIX A	TYPICAL STEAM TRAP ARRANGEMENT FOR STEAM LINE DRAINAGE.....	32
APPENDIX B	TYPICAL PRESSURE REDUCING AND DESUPERHEATING STATION ARRANGEMENT	33
APPENDIX C	SIZING CAHRT INDICATING TYPICAL DRIP LEG DIAMETER.....	34
APPENDIX D	TYPICAL SINGLE LINE DIAGRAM FOR LIQUID FUEL FORWARDING PUMPS	35
APPENDIX E	TYPICAL MP or LP STEAM TIE-IN TO PROCESS	36

1. INTRODUCTION

1.1 SCOPE

This new DEP specifies requirements and gives recommendations for the design and engineering of steam, condensate, demineralised water and storage and boiler feed water systems for offshore and onshore oil and gas production installations, including refineries, chemical and LNG facilities. Functional requirements are provided for the various components included in such systems as boilers, feed pumps, water chemistry guidelines and distribution headers. The detailed technical specifications for the various components are covered by other DEPs.

Hot water and hot oil systems and fuel oil, fuel gas system and process heating furnaces are excluded from the scope of this DEP. Nevertheless, boiler fuel oil pumps configuration which has direct impact on steam system availability has been addressed.

The specific design and engineering of steam generation and consumer equipment is outside the scope of the DEP; however, some minimum requirements related to the system design aspects have been included.

Sparing requirements are considered beyond the scope of this DEP and shall be addressed as part of the Design Class / Value Improvement work processes with requirements identified in Basis of Design (BOD) documents.

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

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

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

This DEP is intended for use in facilities related to oil and gas production, gas handling, oil refining, chemical processing, gasification, distribution and supply/marketing. This DEP may also be applied in other similar facilities.

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

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

1.3 DEFINITIONS

1.3.1 General definitions

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

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

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

The word **shall** indicates a requirement.

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

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Term	Definition
Design Class	Design Class is a categorization defining fit-for-purpose facilities developed through Value Improvement Processes (VIPs) during a project Front End Development (FED) phase.
Process Safety	Process Safety is the management of hazards that can give rise to major accidents involving the release of potentially dangerous materials, release of energy (such as fire or explosion) or both.

1.3.3 Abbreviations

Term	Definition
AC	Accidentally Contaminated
ASME	American Society of Mechanical Engineers
ALARP	As Low As Reasonably Practicable
BFW	Boiler Feed Water
CBD	Continuous Blow Down
DN	Diameter Nominal
DWD	Deposit-Weight-Density
EWLI	Electronic Water Level Indicator
FAC	Flow Accelerated Corrosion
GAC	Granular Activated Carbon
HP	High Pressure Steam (<~68 barg (~1000 psig); >~22 barg (319 psig))
HAZOP	Hazard and Operability Analysis
IBD	Intermittent Blow Down
IPF	Instrumented Protective Function
LP	Low Pressure Steam (<~6 barg (85 psig))
MB	Mixed Bed
MCC	Motor Control Centre
MOV	Motor Operated Valve
MP	Medium Pressure Steam (<~22 barg (319 psig); >~6 barg (87 psig))
MSSV	Main Stem Stop Valve
MWLI	Magnetic Water Level Indicator
NPS	Nominal Pipe Size
NPSH	Net Positive Suction Head
OEM	Original Equipment Manufacturer
PCV	Pressure Control Valve

Term	Definition
ppb	Parts per billion
ppm	Parts per million
PRDS	Pressure Reducing Desuperheating Valve
TSO	Tight Shutoff
TOC	Total Organic Content
VdTÜV	Vereinigung der Technischen Überwachungs Vereine
VGB	Vereinigung Grosskraftwerks Betreiber
VHP	Very High Pressure Steam (>~68 barg (~1000 psig); up to~115 barg (1668 psig))

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets (). Other documents referenced by this DEP are listed in (7).

1.5 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the Administrator at standards@shell.com, using the DEP Feedback Form. The DEP Feedback Form can be found on the main page of "DEPs on the Web", available through the Global Technical Standards web portal <http://www.shell.com/standards> and on the main page of the DEPs DVD-ROM.

1.6 DUAL UNITS

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

2. STEAM GENERATION

2.1 GENERAL DESIGN CONSIDERATIONS

The steam pressures shall be selected to meet the process users and steam turbines requirements and shall comply with the applicable codes and standards for steam generators and piping. Optimisation shall be performed based on energy efficiency and investment, taking into account limits to materials and piping class. Refer to DEP 31.38.01.12-Gen. and DEP 31.38.01.15-Gen.

The steam temperature shall be fixed to provide the maximum degree of superheat for steam turbine consumers with a reasonable cost of equipment and piping due to higher ratings of flanges, seals, materials, etc.

The degree of superheat for the steam supplied to steam turbines shall be sufficient as worked out on the following basis:

- For a condensing turbine section, the exhaust steam quality shall be least 92 % with the "state of the art" steam turbine efficiency or as specified by the steam turbine OEM.
- For a back pressure exhaust turbine or extraction section outlet steam, under normal operation, additional superheating is not required to supply this steam to general process heating uses. However, the desuperheating or tempering requirement of extraction steam should be verified on a case-to-case basis, duly considering partial load operation of the extraction and back pressure steam turbines.

The final selection of the steam temperature shall be verified with connected users and the steam turbine OEM.

The temperature of the steam to the steam distribution headers shall have sufficient degree of superheat to avoid excessive condensation in the distribution network.

In addition to the above requirements, the selected steam temperature shall be within the safe and practicable design and metallurgical limits for the steam generators.

The capacity margin and sparing of steam generators shall be selected according to the design class and project premise considering a wide range of operating conditions. This includes shutdown of the largest steam generator without curtailing the plant operations. In addition, minimum turndown operation and ramp rates shall also be considered. Refer to DEP 00.00.07.10-Gen. for design class tables.

The quality of steam shall be defined based on the steam pressure and intended application.

For low pressure steam, a total solid content of 1 ppm may be considered an adequate quality for heating or similar process end use.

For MP, HP and VHP steam, the following steam quality guidelines shall be considered to avoid formation of deposits on the super heaters, turbines and valves. Refer to (3.12) for steam sampling requirement.

Steam purity guidelines for turbines in continuous operation

Sr. No.	Parameter	Limit	Unit
1	Conductivity* (at 25°C (77°F))	< 0.20	µS/cm
2	Silicic acid (SiO ₂)	<0.02	ppm
3	Total Iron (Fe)	<0.02	ppm
4	Total Copper (Cu)	<0.003	ppm
5	Sodium (Na)	<0.01	ppm

*Following cation exchange

2.2 BOILERS/STEAM GENERATORS BLOWDOWN

Depending on the type of pre-treatment applied, boiler feed water will continuously introduce a certain amount of impurities to a boiler. While pure water leaves the boiler in the form of steam, the impurities remain in the boiler, resulting in a steady increase in the concentration of dissolved solids in the boiler water.

In order to maintain the specified boiler water quality and prevent corrosion and fouling in the boiler and downstream equipment, continuous and intermittent blow down shall be applied.

2.2.1 Continuous Blow Down

The purpose of continuous blow down is to control dissolved solids in boiler water and to maintain the specified water chemistry parameters.

For the design of the boilers serving process units where return condensate contamination is possible and boiler feed water quality is moderate, at least 5 % or higher continuous blow down shall be provided depending upon BFW make up quality.

For combined cycle steam power plants or installations where all the condensate is clean and sourced from turbine condensers only, a minimum 3 % continuous blow down shall be considered in the design which can be optimised during real operation.

A calibrated blow down valve shall be installed closest to the blow down vessel and therefore minimising pipe sections exposed to high velocities of two phase flow.

CBD from each steam generator shall be routed for disposal and heat recovery to a dedicated flash vessel operating at low pressure (LP) applicable for the steam system where the recovered flash steam can be used. The CBD vessel hot water shall be routed to the atmospheric IBD vessel and disposed from the IBD vessel or recycled back to cooling tower, if applicable.

Design shall consider CBD adjusted manually or be ratio controlled as per varying loads to feed water flow ratio. In the case of ratio control, the blow down ratio may be adjusted as needed, to handle long term changes in feed water quality to meet the boiler water specifications.

Automatically controlled continuous blow down based on conductivity or automatically controlled phosphate dosing pumps for boiler drum water pH control shall not be used.

2.2.2 Intermittent Blow Down

Intermittent blow down shall be designed to remove suspended solids and sludge formed in the boiler water. Intermittent blow down can sometimes, in abnormal operating situations or start up, be used to bring the drum level back to normal from high-high level. The IBD system shall be designed to handle such abnormal operation IBD flow rates.

Intermittent blow down shall be routed to the atmospheric IBD vessel. The flash steam shall be vented to a safe location. Hot condensate in the IBD vessel shall be cooled to less than 60°C (140°F) with service water before being discharged to the AC system to avoid flashing and vapour cloud formation in the AC system.

2.3 CBD/IBD PIPING

The CBD/IBD piping shall be designed to handle two phase flow with minimal hammering and vibrations. The CBD/IBD piping shall be adequately sized to allow the transfer of blow down water and steam formed due to continuous flashing inside the piping.

The average maximum velocity in the blow down lines SHALL [PS] not exceed 3.8 m/s (12.5 ft/s) near the flash vessel inlet. As a good practice, IBD valves shall be installed close to the blow down vessels such that flashing fluids directly enter the vessel. In case this is not possible, pipe sizes downstream of the blow down valves shall be selected such that fluid acceleration is gradual and the potential for erosion (e.g. in elbows) can be avoided. Blow down valves shall be suitable for flashing service.

The location of the CBD/IBD flash vessels shall be close to the steam generator and the CBD/IBD piping length shall be minimised.

Horizontal expansion loops shall be used in the CBD/IBD piping.

The pipe supports SHALL [PS] be designed to allow thermal expansions and to limit the line movements that can cause piping system failures due to water hammer induced by a two phase flow.

Vibration analysis for operating conditions for CBD/IBD lines shall be carried out in compliance with DEP 31.38.01.11-Gen. CBD/IBD piping design SHALL [PS] comply with the pipe stress analysis and supports requirements specified under section 3.5 of DEP 31.38.01.11-Gen.

2.4 CBD/IBD FLASH VESSELS

Separate dedicated IBD flash vessels shall be provided for each process steam generator and boiler.

Utility boilers shall have separate CBD vessels from process steam generators. For multiple process heaters, waste heat boilers, the number of flash vessels can be optimized if it can be demonstrated that there is no risk of water hammer and vibrations in the piping and is subject to approval by the Principal.

The provision of diverting CBD to IBD vessel shall be considered in the design to ensure that the CBD vessel can be isolated for inspection and maintenance.

The water droplets carryover from the CBD flash vessels shall be minimised and the dissolved solids concentration in the flash steam shall be guaranteed by the Contractor.

The IBD flash vessel shall also be designed for minimum water droplets with vented steam to avoid unsafe conditions in the area around the IBD vessels.

2.5 SPARING PHILOSOPHY

The capacity and sparing of boilers shall be decided according to the selected design class and project premise. Refer to DEP 00.00.07.10-Gen. for design class. As a minimum, N+ 1 boiler should be installed to ensure that required steam generation capacity is available during the periodic statutory shutdowns and during outages for inspection and maintenance of boilers. The boiler's reliability and steam availability shall be verified to meet the overall plant availability criteria. Utility boilers shall be provided with dual drive on forced draft fans driven with two independent utilities, preferably steam and electricity.

2.6 STEAM LOAD SHEDDING

Steam load shedding shall be considered in the design such that dedicated process plants or steam drives with low impact and highest steam curtailment shall be shut off during steam shortage events.

MOVs shall be provided to isolate the steam supply to the plants and steam drives to be curtailed. All MOVs shall be activated by set point or manual intervention by operator from the control room. At least 20 % of the steam production capacity of one boiler shall be maintained as an additional reserve to restore the steam pressure back to normal.

2.7 PRESTART UP AND OPERATIONAL CLEANING

Prestart-up cleaning of the steam generating equipment and the distribution piping network shall be carried out in accordance with the VGB-R 513 e.

2.7.1 Chemical Cleaning

Chemical cleaning shall be considered as per DEP 70.10.80.11-Gen. and VGB-R 513 e prior to first start, during operational tenure, based on the extent of fouling of the tubes or after major repairs.

The degree of fouling expressed as deposit-weight-density (DWD) is mass deposited per unit surface area in mg/cm^2 . DWD shall be determined by cutting a tube section from the boiler according to NACE TM0199 specification.

Typically, for HP utility boilers the following guidelines are used:

DWD [mg/cm^2]	Condition
$\text{DWD} < 15$	Clean
$15 \leq \text{DWD} \leq 40$	Relatively dirty
$\text{DWD} > 40$	Excessively dirty

Using the guidelines, when $15 \leq \text{DWD} \leq 40 \text{ mg}/\text{cm}^2$, then cleaning during scheduled maintenance outage should be undertaken. When $\text{DWD} > 40 \text{ mg}/\text{cm}^2$, then cleaning should be carried out at the earliest opportunity.

Depending on the quality of the boiler water quality control, after 3-6 years of operation during a scheduled maintenance (or statutory) inspection, a sample for DWD measurement should be taken from a representative area. Depending on the results of the test, a test frequency schedule needs to be established.

A comparison of a visual inspection of accessible areas which shall be ensured in design and a verification of the cleaning process to ensure compliance with the set of procedures provides sufficient verification of the quality of the cleaning activity.

2.7.2 Steam Blowing

All steam generators and associated distribution pipe work shall be blown with steam to ensure the cleanliness of the system and to prevent potential damage of steam turbines and other connected equipment and users. Steam blowing shall be carried out against a target plate. Refer to DEP 61.10.08.11-Gen for prestart up requirement of steam blowing prior to steam admission to steam turbine.

A system specific procedure shall be written by the Contractor for steam blowing. The procedure shall describe in detail all the activities to make a particular system ready for steam blowing. The procedure shall include strategic locations and type of target plates. The procedure shall also define the acceptance criteria in terms of the maximum diameter of indentation and the number of indentations on the target plate.

Silent steam blowing should be preferred over the conventional steam blowing due to a lower steam requirement, uninterrupted blowing and no environmental disturbance.