Onshore Engineering Nigeria
(Operations Support and WRFM)

Opportunity Realization Note

Gbaran Debottlenecking to 1.4 Bscfd by Wet Gas Blending

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- Revisions for review will be issued as R01, with subsequent come as R02 etc.
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- Highlights of sections revised from previous approved issues or reasons for version change are to be listed in the description box
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Signatures for this revision

Role	Name	Signature	Date
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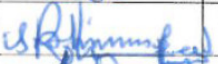
Reviewer	Burahimo Rasheed		16/11/2017
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Additional Agreement Record

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PACO	Ogbe, Eghosa	Y
MCI	Ojemeni, Kenechi	Y
Civil	Asilonu, Collins	Y

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Abbreviations

ACAL	Asset Control and Assurance List
AG	Associated Gas
AIPSM	Asset Integrity Process Safety Management
ALARP	As Low As Reasonably Practicable
BfD	Basis for Design
Bscfd	Billion standard cubic feet per day
Bpd	Barrels per day
CCMP	Corporate Change Management Panel
CPF	Central Processing Facility
DCAF	Discipline Control and Assurance Framework
DEM	Design and Engineering Manual
DEP	Design and Engineering Practice
DPR	Department of Petroleum Resources
EGASPIN	Environmental Guidelines and Standards for the Petroleum Industry in Nigeria
EGGS	Eastern Gas Gathering System
F&G	Fire and Gas
GHG	Greenhouse Gas
GSA	Gas Sales Agreement
HAZID	Hazard Identification
HAZOP	Hazard and Operability
H & M	Heat and Mass
HEMP	Hazard and Effect Management Process
HP	High Pressure
HSSE	Health Safety Security and Environment
IAP	Integrated Activity Plan
ISO	International Standard Organization
LP	Low Pressure
MCI	Materials Corrosion and Inspection
MMscfd	Million standard cubic feet per day
MoC	Management of Change
NAG	Non Associated Gas
NLNG	Nigeria Liquefied Natural Gas
OHSAS	Occupational Health and Safety Assessment Series
OSD	Onstream Date
PACO	Process Automation Control and Optimization
PAS	Process Automation System
SAP	Systems, Applications and Products
SIF	Safety Instrumented Function
SIL	Safety Integrity Level
SIS	Safety Instrumented System
SP	Social Performance
SPDC	Shell Petroleum Development Company
TEG	Tri-ethylene Glycol
TNP	Trans-Niger Pipeline
VIP	Value Improvement Practice
WRFM	Well, Reservoir and Facility Management
XHP	Extra High Pressure
XXHP	Extra Extra High Pressure

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Executive Summary

Gbaran CPF gas dehydration trains was recently debottlenecked from 1.2Bscfd to 1.25Bscfd. There is plan to further expand the plant capacity to 1.4 Bscfd to meet SPDC gas supply obligation to NLNG. This can be achieved by blending ca. 150 MMscfd of undehydrated gas with 1.25 Bscfd of dehydrated gas and still be within customer specification of maximum 5°C water dewpoint at 95 bara. The critical success factors for this planned expansion in the plant capacity is simplicity of the design and speedy execution. Wet gas from the slug catchers will bypass the dehydration trains and blend with dehydrated gas upstream the metering skids. The existing XXHP separator (with capacity of 180 MMscfd of gas and 60 Mbpd of liquid) in the facility will be used to further remove free liquid from the wet gas stream before blending it with dehydrated gas upstream of the metering skids. The OSD for the project is estimated to be Q2, 2018.

1. Project Background

The Gbaran Ubie central processing facility (CPF) consist of a number of oil and NAG wells which are tied into associated remote manifolds from where the fluids are transported to the CPF for processing and export. The CPF is 1250 MMscfd gas (NAG +AG) and 120 Mbpd liquid processing facility that delivers sales gas to Nigeria Liquefied Natural Gas (NLNG) at 90-100 barg and stabilized oil/condensate to Bonny crude oil terminal via the TNP.

Gbaran CPF gas dehydration trains was recently debottlenecked from 1.2Bscfd to 1.25Bscfd. There is plan to further expand the plant capacity and this can be achieved by blending undehydrated gas from the slug catchers with dehydrated gas and still be within customer specification of maximum 5°C water dewpoint at 95 bara.

Based on assessments carried out, the option of blending undehydrated gas from the slug catchers with the dehydrated gas has been proposed. The option involves routing the slug catcher gas from the dehydration inlet manifold to the XXHP separator for further free liquid removal and blending the off gas with trains 1 and 2 dehydrated gas upstream of the metering skid.

1.1. Opportunity

There is an opportunity to increase gas supply to NLNG from Gbaran CPF to 1400 MMscfd by blending about 150 MMscfd of undehydrated gas with 1250 MMscfd of dehydrated gas and still meet the export gas quality.

1.2. Project Value Drivers

The value drivers for this project are Schedule and gas volume. Much value will be derived from this project if the proposed modification can be in place within a short time to take advantage of available gas volumes from the current wells.

1.3. Purpose

The purpose of this document is to set out the basis for the proposed modifications required to achieve the desired goals, describe the concept as well as highlight possible challenges and planned mitigation measures considered.

2. Business Premises

2.1. Objective

The objective of this project is to increase gas supply volume to the NLNG from Gbaran node by about 150 MMscfd within the shortest possible time without jeopardising current export gas quality while ensuring asset integrity.

2.2. Key Milestones

- Completion of concept
- MoC approval
- Completion of design
- Procurement of materials
- Installation of additional tie-points within available IAP window
- Piping modification of XXHP separator
- Hook up to XXHP separator gas outlet to trains 1 & 2 dehydrated gas upstream the metering unit.
- Pre-start up audit
- Commissioning and start-up

3. Technical Premise

3.1. Technical Scope and Interfaces

The main scope of the modification involves modification of the XXHP separator piping linking the dehydration inlet manifold which will now serve as the inlet into the vessel, and routing of the gas outlet line to upstream of the metering unit. The concept is to backflow the slug catcher gas from the dehydration inlet manifold to the XXHP separator to further remove free liquid, and route the gas from the separator to blend with dehydrated gas upstream of the metering unit. Refer to section 4.2 for details of technical scope of work.

3.2. Design Philosophy

The adopted design philosophy for the project is based on the existing design philosophy of the Gbaran CPF. The design is based on a NAG system availability of 98%.

3.3. Regulations and Standards

The Gbaran CPF was designed in accordance with Shell standards and specifications, to fulfil the functional intents of Shell and its partners. The plant is operated in accordance with relevant Nigerian laws and regulations. The modification and operation will follow the same regulations.

4. Scope Details

4.1. Scope Description

The concept takes advantage of existing facilities in the CPF to increase sales gas volume to the export market (NLNG). The project will utilize the existing XXHP separator in the CPF which is not in use as there are no XXHP oil wells in the Gbaran node. Utilities (instrument air for actuating shutdown and control valves) will be from the CPF utilities.

4.1.1. Control Philosophy

To maintain the blended gas within the export gas specification of 5°C (maximum) water dewpoint at 95 bara, the XXHP separator outlet gas flow will be controlled to ensure the correct ratio of undehydrated to dehydrated gas is blended. The XXHP separator outlet gas pressure will also be controlled to allow blending without backing out the dehydrated gas flow. The control system design will prevent wet gas flow to export when both dehydration trains are not on stream, and an override to reduce or stop undehydrated gas flow whenever the blended gas goes above the export gas specification.

In addition, the control system design must ensure that the sequence for flow reduction in the event of reduction in export volumes due to reduced nomination from NLNG will be; first a reduction/stop of undehydrated gas flow, before reduction in dehydrated gas flow.

The control scheme will be fully detailed in the process control narrative during the design stage.

4.1.2. Safeguarding

The existing SIFs on the XXHP separator will be retained and re-configured to provide protection against overpressure and gas blow-by. The implementation details will be described in the safeguarding narrative to be developed during the project design stage.

4.1.3. Interface with Existing Asset

This project will rely on the availability of the TEG dehydration units to ensure that the blended gas stream (export gas) meets the required water dew point specification. The existing XXHP separator will be utilized for further liquid removal from the wet gas stream. The control system will be integrated to the PAS while the safeguarding system will be integrated to the SIS of the facility.

4.1.4. Givens

- The required vessel to be used is in place
- The required export gas spec is 5°C water dew point (maximum) at 95 bara
- The facility is currently meeting the dew point spec at 1.25 Bscfd gas production rate

4.1.5. Concept Logic and Decisions

The design intent of the project is to increase sales gas volume from Gbaran node with minimal plant modification and still meet the customer spec. as specified in the GSA.

Table 1: Sales Gas Specification (Source – Gbaran Phase 1 Basis for Design)

Gas Entry Point Conditions into EGGS-2 at Gbaran CPF	
Operating pressure (minimum / maximum)	70 / 105 bara
Operating temperature (minimum / maximum)	20 / 50 °C
Maximum water dew point	5°C at 95 bara
Gross heating value	1138 – 1230 Btu/SCF

4.1.6. Operating Philosophy

The Gbaran CPF is designed with capability for automatic fail-safe of the facility. Control and safeguarding of the plant is from a central control room with fully functional PAS and SIS respectively. The proposed debottlenecking project will follow the same operating philosophy.

4.2. Detailed Engineering Scope of Work

The main scope of the project Detailed Engineering shall consist of the following:

4.2.1. Process Engineering

- Preparation of H&M balance
- Preparation of process engineering flow scheme
- Preparation of process safeguarding flow scheme
- Addendum to the facility process safeguarding memorandum
- Sizing of new gas inplot piping

4.2.2. PACO

- Detail engineering and design activities to support procurement of required field instrumentation, cabling and required ancillaries, installation and integration into existing Gbaran CPF PAS and SIS.
- Only deliverables essential for accurate procurement, installation, integration, commissioning and operation will be developed.

4.2.3. Mechanical Engineering

- Tie-in list and schedule
- Isometric drawings
- Materials take-off
- General arrangement drawing

4.2.4. Civil Engineering

- Design and verification of pipe supports/foundation
- General civil plot plan

4.2.5. Technical Safety

- HAZOP study
- Construction HAZID study

4.2.6. MCI

- Corrosion assessment and material selection report.

4.3. Construction Scope of Work

4.3.1. PACO

- Installation of new and replacement field devices, including wiring and integration into existing Gbaran CPF PAS and SIS.
- Upgrade of metering system in the facility to accommodate up to 800 MMscfd per metering run.

4.3.2. Mechanical

- Modification and installation inlet piping to the XXHP separator
- Modification and installation of gas outlet piping from XXHP separator to downstream trains 1 and 2 glycol scrubbers
- Installation of new restriction orifice downstream each dehydration train glycol scrubber to limit flow to 630 MMscfd per train.

4.3.3. Civil

- Construction of additional supports for XXHP separator inlet and gas outlet piping

4.4. Schedule

The debottlenecking project is schedule driven and much of the value of the project depends on speedy execution and commissioning of the modification. It is expected that the project will be onstream in Q2 2018.

5. Existing and New Facility Description

5.1. Existing Facility Description

The major function of the Gbaran Ubie CPF is to collect NAG from several reservoirs and separate the gas from condensate and associated water at about 92 to 105 barg. The gas is then dehydrated and metered, in two trains each of 625 MMscfd capacity, prior to export via the EGGS pipeline to NLNG. The condensate and oil are stabilized in a four-stage separation process before export to Bonny terminal via TNP.

NAG enters the CPF at around 92 – 105 barg and all the fluids from each bulkline passes to the slug catcher dedicated for that bulkline. The slug catcher is designed as a two-phase separator with schoepentoeters and wiremesh demisters to reduce liquid carry over into the gas treatment process. There are six NAG slug catchers, namely; Zarama, Koroama-1, Koroama-2, Kolo Creek, Gbaran and Epu slug catchers. Gas from the six slug catchers is combined in a manifold with compressed AG from the oil/condensate stabilization trains. The resultant NAG + AG is split between two gas dehydration trains. Each train consists of an inlet cooler, a separator, a glycol contactor, and a downstream scrubber. Any entrained water in the gas is removed by the use of tri-ethylene glycol in the dehydration train to achieve a water dew point of a maximum of 5^{o}C at 95 bara, before it is metered to fiscal standard and delivered to NLNG.

The facility also comprises of two oil/condensate stabilization trains. Each stabilization train is in the conventional flow station arrangement and it has an XHP separator, HP separator, LP separator, surge vessel, booster and export pumps. There is also an XXHP separator which is currently positively isolated and not in use since there are no XXHP wells in the node. Each stabilization train is sized for 60000 bpd gross liquid. There are three test separators; XXHP (currently positively isolated and not in use) with liquid capacity of 30000 bpd, XHP with liquid capacity of 15000 bpd, and HP/LP with liquid capacity of 15000 bpd. The XHP, HP and LP separators operates at 38 barg, 12 barg and 3.5 barg respectively. The surge vessel operates at about 0.5 barg.

Condensate is stabilized in Train 1 while oil is stabilized in Train 2. Condensate from the slug catchers is sent to a condensate header (XHP) and further to Train 1 XHP separator operating at 38 barg. In the event that the oil export line is not available, NAG production continues by producing condensate to the condensate storage tank (90000 barrels capacity) and spiking condensate from the tank into the gas export line EGGS-2. There are four condensate spiking pumps with capacity of 7000 bpd each. When the oil export route is available, the tank is emptied using a condensate return pump (with capacity of 30000 bpd) to Train 1 surge vessel from where it is pumped to the oil export line.

AG from the condensate/oil stabilization trains is combined and compressed. The LP separator and Surge Vessel off-gas is initially compressed in a booster compressor (5 MMscfd and 10 MMscfd capacity for the first and second stages respectively), which raises it to HP separator pressure. This is combined with HP separator off gas and compressed in a two-stage main compression to dehydration pressure of about 92 – 100 barg. Gas from the XHP separator enters at the interstage of the main compression. Each main compression train is sized for 60 MMscfd in the first stage and 90 MMscfd in the second, and there are two of such trains. Below is a simple schematic of the process.

5.2. Proposed Modification

Below is a schematic of the proposed modification. It shows the bypass gas stream flowing from the dehydration inlet manifold to the XXHP separator and blending with dehydrated gas from trains 1 and 2 before metering and export.

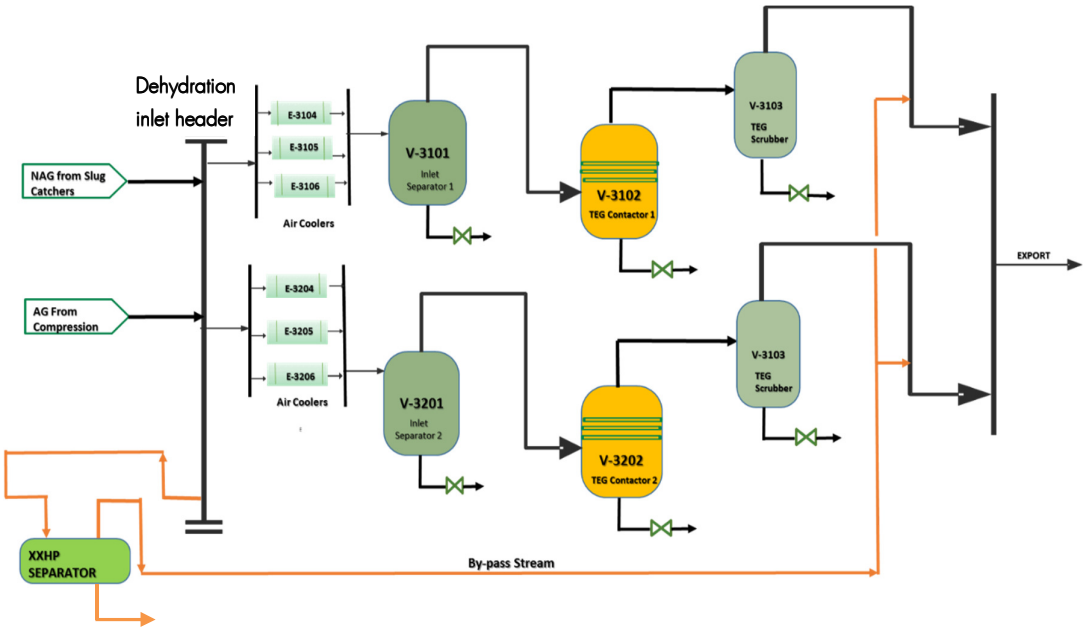

Figure 4.1 - Wet gas (by-pass stream) blending schematic

6. Design Life

The Gbaran CPF has a design life of 30 years. The facility has been in operation for over 7 years. The proposed modification will have a design life not lower than the remaining life of the plant.

7. Risk and Challenges

The table below highlights some key risks and challenges associated with the wet gas blending project.

Table 7.1: Risk Table

Risk	Impact	Severity	Controls & Mitigation
Exporting of off-spec gas into	Internal corrosion of inlet / gas outlet of XXHP separator, piping downstream glycol scrubbers and export pipeline (EGGS-2) due to water drop out.	H	• Effective dehydration in place for 1.25 Bscfd of gas. • Existing corrosion inhibition injection into the EGGS-2 line. • Effective control system to be designed to cut back flow of wet gas when off-spec export gas is detected. • Appropriate material selection to be done for new piping systems to mitigate corrosion.
Concurrent operation	Creation of hazardous environment within the Gbaran CPF	H	Construction to be done in a safe manner and in accordance with plant SIMOPS. Shutdown window to utilized.
Unavailability of IAP window for tie-in and shutdown works	Delay in completion of project	H	Take advantage of planned shutdown window to complete tie-in works.

7.1. Other Risk and Challenges Considered

7.1.1. Installation Space Optimization

A constructability review on site should be carried out to properly identify piping route for the project and construction implications and requirements. Consideration should also be given to requirement for adequate civil structure to carry the pipings.

7.1.2. Metering

The export gas meters can measure maximum of 700 MMscfd per metering run. For this project, upgrade of the export meters should be done to move the capacity to ca. 800 MMscfd per metering run for adequate metering so value is not lost on gas export to the customer.

8. Execution Strategy

8.1. Resources and Budgets

This project will be funded by the Asset team and executed by the Onshore Engineering (Operations Support & WRFM, Discipline Engineering, Engineering Services) and Asset Engineering teams.

8.2. Project Control Assurance Plan

In addition to the mandatory HEMP processes such as HAZOP and SIL, the concept and resulting design will be subjected to the DCAF process and a number of other fit-for-purpose business and project assurance processes. The project will be subjected to the following assurance events and VIP's

- Technical change control
- Independent design review
- Operation readiness review
- Non-technical risk review
- Pre-start up audit
- Constructability review

9. Feed Characteristics

9.1. Fluid Composition

Below is the composition of the undehydrated and dehydration gas streams to be blended, as obtained from the Gbaran CPF Unisim model.

Table 3.1 – Summary of compositions for the dehydrated and undehydrated gas streams (From Gbaran Unisim Model)

Streams	Wet Gas from Dehydration inlet manifold	Wet Gas from XXHP Separator	Dehydrated Gas from Dehydration Trains
Operating Pressure (bara)	98	98	97
Operating Temperature (°C)	40	40	38
Component Mole Fractions			
CO2	0.017651	0.017654	0.006862
N2	0.000212	0.000212	0.000131
C1	0.885014	0.885178	0.948711
C2	0.053908	0.053917	0.030956
C3	0.019926	0.019929	0.007861
i-C4	0.004009	0.004010	0.001199
n-C4	0.005061	0.005061	0.001524
i-C5	0.002179	0.002179	0.000525
n-C5	0.001600	0.001600	0.000389
n-C6	0.000007	0.000007	0.000002
_CP *	0.002039	0.002038	0.000485
_CH *	0.004609	0.004607	0.000879
_NC5 *	0.001088	0.001088	0.000263
_NC6 *	0.000592	0.000592	0.000121
_BNZN*	0.000331	0.000331	0.000055
_BCH *	0.000482	0.000480	0.000035
_NPHT*	0.000076	0.000075	0.000000
_X180*	0.000002	0.000002	0.000000
_15A *	0.000014	0.000014	0.000000
_X350*	0.000000	0.000000	0.000000
_28B *	0.000000	0.000000	0.000000
_NC10*	0.000000	0.000000	0.000000
_NC16*	0.000000	0.000000	0.000000
_29A *	0.000000	0.000000	0.000000
_X580*	0.000000	0.000000	0.000000
_X600*	0.000000	0.000000	0.000000
_X800*	0.000000	0.000000	0.000000
_X820*	0.000000	0.000000	0.000000
H2O	0.001199	0.001024	0.000002
TEG	0.000000	0.000000	0.000000

10. Health, Safety, Security & Environment Requirements

It is SPDC's Policy that all activities shall be planned and executed in a manner that:

- Preserves the health, safety and security of employees, the employees of SPDC contractors, and all members of the public;
- Minimizes the impact of its operations on the environment,
- Is sensitive to the needs and concerns of the host communities.

Also as a part of the Shell group, SPDC has adopted the Shell Group Health, Safety and Environment Policy and this will guide every aspect of the project throughout its lifecycle.

10.1. HSSE & SP Control Framework

The project activities shall be carried out in line with the HSSE & SP Control Framework. Primarily, compliance with DEM1 and DEM2 requirements will be met. Design integrity will be assured in line with AIPSM guidelines.

10.2. Health and Safety

There are typically high safety risks associated with working in a brown field location. These risks are further increased by the requirement for speedy completion of project works. The work therefore has to be planned to ensure safe and continuous operation for SHELL, Contractor and personnel while construction is ongoing. The key hazard associated with the project is hydrocarbon under pressure.

10.3. Risk Assessment

A risk assessment of the modification is necessary to highlight the risks associated with the various aspects of the project. A risk assessment was done for the planned plant modification as input to the MoC submission. HAZOP and other design risk assessment measures should be executed during detail design.

11. Operations and Maintenance Requirements

11.1. Existing Operations Organisation

The project will not add to the number of personnel required to man the facility and the existing operating philosophy will suffice. The operation of the new modifications will be in line with the existing Gbaran CPF operations philosophy. The Production Unit Manager Gbaran is responsible for all activities in the field.

11.2. Maintenance Objectives & Strategies

The objective of Maintenance and Technical Integrity is to safeguard the technical integrity of assets and ensure availability / reliability, at lowest possible life cycle cost, and that risks are reduced to ALARP. Maintenance includes inspection activities.

The strategy appropriate to each item of equipment will be established and will be included in the maintenance plan in SAP. The facility design and layout will ensure a high degree of maintainability. Frequent maintenance activities should be designed out (minimum intervention) or, at least designed to facilitate safe and efficient execution of any maintenance activity.

11.3. Regulatory Regime

It is mandatory for SPDC as a licensee under the Nigeria Petroleum Act to comply with all the regulations laid down in the following:

- Nigeria Mineral Oils (Safety) regulations, 1997 (DPR)
- Oil and Gas Pipeline Regulations, 1995 (S.1.14)
- Factory Act Decree, 1987
- EGASPIN, 2002 (DPR)

The proposed plant modification shall be designed and built to meet the requirement of the regulations and shall also meet the requirement for certification to ISO-14001 and OHSAS 18001 standards.

11.4. Operations Functional Requirements

Operations functional requirements are based on feedback and lessons learnt from practical experience of operations and maintenance. They are limited to essential key operational issues that must be considered in facilities design to avert a reoccurrence in new projects.

It is SPDC Production Directorate philosophy that facility designs shall ensure that;

- *Production facilities are equipped with electronic instrumentation and automation systems.*

The proposed modification will be equipped with this feature.

11.4.1. Availability and Reliability

The Gbaran CPF NAG system has a target availability of 98% from the Gbaran Phase 1 BfD. It is not envisaged that the proposed modification will impact the overall availability of the plant.

11.4.2. Corrosion Management

Appropriate materials should be selected for the proposed modification to mitigate corrosion. Adequate material selection would be carried out in the detailed design phase of the project.

11.4.3. Update of Existing Documentation

Existing drawings, documents and procedures for the Gbaran CPF shall be updated and signed off by the project team and handed over to the Asset team as part of project hand over documentations to the Asset team.

11.5. Greenhouse Gas and Energy Efficiency

The planned modification will not result in increase in venting and indirect emissions. The current GHG and Energy Efficiency plan will be updated at the appropriate ACAL cycle by the asset team.

12. Design Codes, Standards, and Legislation

Standards form the primary source of reference during the project, and also partly the criteria against which the project may be audited. The design for the project should conform to the standards prevailing in the Group. In case of conflict, the regulations, codes and standards listed shall be applied in the following priority

a) Government Legislation, National Regulations, Statutory Requirements
b) Project Specifications
c) SPDC Specifications and Standards
d) Shell DEPs
e) Industry Standards

Latest editions of all Codes and Standards on the issue date of this specification shall be applicable. Deviations from applicable rules, codes and standards shall be subject to written consent from the Principal.

13. References

1. Gbaran Ubie Basis of Design GBRG1-E15811-G11-00001
2. Technical Note: Gbaran Debottlenecking to 1.4 Bscfd by Wet Gas Blending SPDC-2017-10-00000124, Oct. 2017