Qatargas Flare Reduction Program

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ABSTRACT

Qatargas is the largest Liquefied Natural Gas (LNG) producer in the world delivering 42 million tonnes per annum (MTPA) of LNG. Routine baseline flaring is encountered during normal LNG plant operations due to the essential requirement of maintaining purge gas flow within the flare system to prevent air ingress and consequent explosion hazards. During non-routine facility trips, restarts or planned facility shutdowns, process gas is also flared per operational requirements.

Operational excellence initiatives on source reduction and plant reliability, and flare reduction engineering projects have successfully reduced flaring by more than 56% between 2011 and 2014. A comprehensive purge gas reduction project was completed in December, 2013 at the 4 LNG mega-trains which reduced baseline purge flaring by approximately 45%. Additionally, Qatargas’ $1-billion Jetty Boil-off Gas Recovery (JBOG) facility, that commenced operations in October 2014, reduced LNG loading-related flaring by nearly 90% at all LNG ship-loading berths in Ras-Laffan Industrial City. Qatargas is exploring long-term Flare Reduction Projects (FRP) to re-route off spec gas encountered during process events at our LNG mega trains instead of flaring.

This paper provides an overview of Qatargas’ flare management approach, main drivers and challenges for flare reduction and the various initiatives currently underway to manage and minimize flaring. These include the major capital projects noted above, as well as, enhanced awareness, monitoring and reporting, and operational source reduction successes.
Facility and Flare Systems Overview

Qatargas’ LNG operations are based in Ras Laffan Industrial City (RLIC), Qatar, and centered on the four LNG assets described below.

- **Qatargas 1 (QG1):** Three conventional C3MR LNG trains (Trains 1-3). Commenced operations in 1996. Each train has a production capacity of 3.3 MTPA (total QG1 production of 10 MTPA). Offshore facilities include the manned North Field Bravo (NFB) complex with three wellhead production platforms.

- **Qatargas 2 (QG2):** First mega-trains in the world, each with a capacity of 7.8 MTPA. Commenced operations in 2009. Both trains (Trains 4 and 5) utilize the Air Products AP-XTM hybrid liquefaction process which allows for higher LNG production by adding a third Nitrogen (N2) refrigeration cycle to the conventional C3MR process. Offshore facilities include three unmanned wellhead platforms.

- **Qatargas 3 (QG3) and Qatargas 4 (QG4):** Although separate assets with different shareholders, both facilities are operated jointly as Qatargas 3&4 (hereinafter referred to as 'QG3&4') by a combined operations team. QG3&4 consists of two LNG mega-trains (Trains 6 and 7) based on the AP-XTM process and each with a production capacity of 7.8 MTPA. Train 6 (QG3) commenced production in late 2010 and Train 7 (QG4) in early 2011. Offshore facilities include three unmanned wellhead platforms.

In addition to LNG trains, Qatargas also operates the Laffan Refinery (LR), which commenced operations in 2009 with a nameplate processing capacity of 146,000 barrels per stream day (BPSD). Qatargas, through its Ras Laffan Terminal Operations (RLTO) group, is also the operator (on behalf of other producers within RLIC) of multiple hydrocarbon storage tank farms and loading facilities as well as a Common Sulfur Plant (CSP). These common tank farms cater to LR feedstock and products, Liquefied Petroleum Gas (LPG), Gas to Liquids (GTL) plant products and low sulfur condensate. The common loading facilities include Liquid Product Berths (LPBs) and an offshore Single Point Mooring (SPM) for field condensate loading.

The large number of operating assets and facilities described above require multiple flare systems, which can be described as follows:

- **On-plot Flares (within main LNG plant site):**
  - QG1: Four independent flare stacks. Main stack includes separate headers for dry, wet and sour gas. Steam-assisted smokeless tips on dry and wet headers. Separate upstream (inlet reception) and on-plot LNG tankage flare stacks.
  - QG2 and QG3&4: Large combined flare system for all four mega-trains. Two 200m flare stacks. Separate headers for dry, wet and sour gas. Steam assisted smokeless tips on dry and wet headers.

- **Off-plot Flares (various locations outside LNG plant site):**
• LR: Single stack and header to flare off gases from refinery units as well as LPG, hydrogen and sour gas during plant upsets.

• Common Lean LNG Tankage: Single stack with main and spare headers to flare Boil-off Gas (BOG) from storage of lean LNG supplied by four Qatargas mega-trains and two RasGas mega trains.

• Common LPG Tankage: Two single-header stacks to flare BOG (only required during BOG compressor upsets).

• LPG Loading: Single stack and header to flare BOG from LPG ship loading (only required in case of ship BOG compressor upset).

• LNG Loading: Each of Qatargas’ four LNG berths or jetties are equipped with a dedicated flare stack to flare BOG generated during ship loading.

• Offshore: One dedicated offshore flare platform at the QG1 NFB complex and dedicated flares on the three QG3&4 unmanned wellhead platforms (pilots not continuously lit, required for emergency use only).

Building on lessons learned from Qatargas’ conventional trains, the LNG mega trains were designed and constructed with the following inherent (existing) flare reduction measures:

• Shared Flares: One set of sour gas, wet gas and dry gas flares serve four LNG mega-trains as discussed above. This minimizes continuous flaring due to additional purge and flame shaping gas.


• Inter-Asset/Train Process Crossovers: Uni-directional interconnections available between Inlet Reception (IR) facilities for QG2 (to QG1) and QG3&4 (to QG2) to re-route offshore gas during full start-up (instead of flaring). Acid Gas Removal (AGR) and Natural Gas Liquid (NGL) Fractionation units of two mega-trains interconnected with crossover lines to re-route gas during trips and start-ups instead of flaring.

• Process Equipment Design and Sparing: All four mega-trains equipped with spare offgas and BOG compressors as well as spare Pressure Relief Valves (PRVs) to minimize flaring during compressor downtime or PRV repair.

The Qatargas LNG facilities and on-plot flare system is shown in Figure 1.
Drivers for Flare Reduction at Qatargas

Drivers for flare reduction are multi-faceted and include Qatargas’ Direction Statement and Corporate Social Responsibility (CSR) commitment and alignment with the Qatar National Vision (QNV) 2030, the State Ministry of Environment regulatory flare reduction requirements, and the Company’s obligations to its stakeholders, including the community in which it operates. Qatargas’ multi-faceted drivers for flare reduction and their interlinkages are described in Figure 2 below.

Figure 2: Qatargas Flare Reduction Drivers

Current Flaring Performance and Sources

A summary of Qatargas’ flaring performance from 2011 until 2015 (inclusive) is provided in Figure 3 for all LNG assets. Flaring from Qatargas’ LR and RLTO assets is very minor (approximately 2% of total flaring) and is not discussed further. As evident from Figure 3, Qatargas has sustained significant reductions in flaring, approximately 70%, since 2011. These reductions were achieved based on the key initiatives listed below.
- Establishment of Flare Management Teams (FMTs) for each asset.
- Awareness, recognition and commitment to reduce flaring.
- Enhanced monitoring, tracking and reporting which facilitated a continual flare management focus.

- Operational source reduction comprising minimization of flaring during train trips, shutdowns and restarts.
- Increased experience with mega-train operation.
- Increased plant and equipment reliability.
- Flare Reduction Projects with notable reduction of nearly 45% in purge rates at the mega trains, since December 2013

Figure 3: Qatargas Flaring Performance (2011 - 2015)

Figure 4 illustrates Qatargas’ main flaring sources since 2011 and how they have been managed and reduced. Flaring volumes from train and unit trips reduced approx. 70%, planned shutdowns approx. 88% and baseline purge gas flaring approx. 45%. Other flaring sources, which include small unit trips, short-term off-spec production and unclassified flaring events are reduced by 40%. Tankage flaring which accounts for only 0.03% of total flaring has remained at a low level. Jetty Boil off Gas (JBOG) flaring (i.e., BOG flared from LNG ship loading) accounting for approximately 30% of total flaring at LNG assets; has been reduced by nearly 90% due to BOG recovery at the Jetties starting from October 2014.
Qatargas Flare Management Approach

Qatargas’ Flare Management Approach is summarized in Figure 5 and comprises three main pillars with the overall aim of minimizing flaring while providing due consideration to:

- **Operational Flexibility**: The inherent nature of a LNG plant requires flaring during process events; and

- **Safeguarding Asset Integrity and Process Safety**: The flare system is primarily, a process safety device and requires continuous baseline purge gas flaring to prevent air ingress and maintain its operability at all times.

**Figure 5: Key Pillars of Qatargas’ Flare Management Approach**

**Flare Reduction Pillar #1: Enhanced Awareness, Monitoring and Reporting**

The first step of Qatargas’ Flare Management Approach is promoting and maintaining awareness and organizational buy-in of the importance of flare reduction, coupled with continual improvement in flare measurement, tracking and reporting to provide a sound basis for flare minimization at an operational level. This is accomplished through the key initiatives described below.

**Flare Management Teams (FMTs)**

Multi-disciplinary teams have been established for each LNG asset, which provide a common platform for internal stakeholders to coordinate their efforts on flare reduction. These FMTs meet regularly (minimum monthly) to review flaring performance for each asset, and explore measures (operational, maintenance or best industry practice) to minimize flaring. A summary of key initiatives championed by the FMTs is provided below.

- Minimization of non-routine flaring events and maintenance of facility flaring at minimum-required baseline purge gas levels.
- Flare reduction during process events through optimized operational practices and procedures. A smaller Operations team has recently been established as a FMT sub-
group to review mega-train trip, shutdown and restart scenarios and incorporate improvements in current procedures to minimize flaring.

- Surveillance and mitigation of ‘bad actors’, i.e., units and components causing frequent flaring. This mitigation may include relatively simple operational fixes or more detailed engineering and reliability analyses.
- Flare meter performance tracking and implementation of quarterly and annual calibration/validation programs.
- Minimization of differences (‘deltas’) between end-of-line flare meter readings and baseline purge gas rates. These differences are typically accounted for by small flaring sources such as passing valves. A recent mitigation measure championed by the FMTs was the acquisition of an acoustic meter to verify valves passing to flare. A regular valve monitoring program is currently being implemented using this acoustic meter.
- Review and improvement of flaring calculations and reporting procedures. Discussion and alignment on external stakeholder queries or clarifications on submitted flare reports.

Flare Reduction Pillar 2: Operational, Reliability and Maintenance Initiatives

The two case studies included in this section describe how operational, reliability and maintenance initiatives have been successfully implemented at LNG train turnarounds and operational flare reduction at mega trains

LNG Trains Turnaround Flare Reduction

Qatargas’ significant improvement in turnaround flaring performance is depicted in Figure 6, starting with the first year of Train 7 (QG4) operations in 2011. From 2012, Qatargas started developing turnaround specific flare reduction plans that involved analyzing historical flaring performance associated with each train shutdown and startup sequence and developing operational and engineering solutions to curtail the flaring. This helped Qatargas in reducing turnaround flaring by 88% from 2012 to 2015.

Qatargas Mega-Train Operational Flare Reduction (2012-Present)

Flaring reduction at Qatargas’ mega-trains has been characterized by optimization of operational procedures, particularly during train trips, shutdowns and restarts. This sub-section describes how these improvements have been implemented at the mega-trains to reduce flaring during actual process events. For illustrative purposes, a process event called a Cold Section Trip, which is the most common type of LNG train upset, is described herein. Similar procedures have
also been developed and implemented for other process events such as Hot Section Trips and Full Train Restarts.

It should be noted that each process unit within a mega-train is designed to be operated at a specific minimum turndown rate (i.e., minimum process throughput) to achieve the required specification for natural gas processing and liquefaction. These turndown rates therefore represent the natural maximum limit for flare reduction based on operational intervention only. Process throughputs below these rates will not allow the units to meet gas specification requirements resulting in flaring of gas throughput.

A cold section trip is an upset of the refrigeration section (Units 05-08) of the mega-train and typically results from a trip of the MCHE or the main propane or Mixed Refrigerant (MR) compressors as shown in Figures 7 and 8. During a cold section trip, flaring results from Acid Gas Removal (Units 02) and NGL Recovery (Unit 04) due to back-pressure as flow to the cold section is stopped. The magnitude of this flaring depends on how quickly flare reduction procedures can be applied following the trip.

- **Earlier Qatargas Operational Practice (Figure 7):**
  - Feed gas reduced from 1,460 Million Standard Cubic Feet per Day (MMSCFD) to 600 MMSCFD immediately following cold section trip (*earlier minimum turndown recommended by process licensor to keep Unit 04 operational)*.
  - Flaring continues from Units 02 and 04 as shown in Figure 5 until cold section is restarted.

**Actual Event:**
- Mega train cold section trip in 2011 - approximately 121 MMSCF flared.

- **Flare Reduction Practice (Figure 8):**
  - Feed gas now reduced to 450 MMSCFD following cold section trip (*new minimum turndown for Unit 04 based on operational experience*).
  - Lean gas from Unit 04 exported to Qatar Petroleum (QP) national grid (≤ 250 MMSCFD).
- Same lean gas also supplied to combined asset fuel system from tripped train (≤ 150 MMSCFD). Fuel gas supply from other operating train minimized.
- Due to feed gas reduction to 450 MMSCFD and export to QP and fuel gas system from Unit 04 (total 400 MMSCFD), wet gas flaring from Unit 02 is eliminated and dry gas flaring from Unit 04 reduced from 450 MMSCFD (earlier practice) to 50 MMSCFD.

**Actual Event:**
- Mega train cold section trip in 2015 - approximately 22 MMSCF flared.

![Image](image-url)

**Figure 8: New Flare Reduction Practice – Mega-Train Cold Section Trip.**

**Flare Reduction Pillar 3: Capital Projects**

As noted in Figure 4, the current major flaring sources at Qatargas’ LNG trains include jetty, baseline purge gas and train and unit trips. The high volume of jetty flaring is common to all LNG trains, however, flaring from train and unit trips and purge is more significant at the mega-trains (as compared with QG1) due to their larger throughput and common flare system and cannot be reduced through operational means alone. An overview of the engineering projects currently being implemented by Qatargas to minimize these major flaring sources is provided in the subsections below.

**JBOG Recovery Project**

Qatargas has implemented a major project to recover Jetty Boil Of Gas (JBOG), which otherwise used to be flared. The $1 billion JBOG Project is the largest project of its kind in Qatar. It collects BOG from LNG ships and compressed at a central facility. The compressed gas then sent to LNG producers to be consumed as fuel or converted back into LNG. The JBOG generation process is illustrated in Figure 9 below.
The JBOG facility, commissioned in October 2014, now sustains recovery of nearly 90% of BOG generated at the six (6) jetties in Ras Laffan Port, used by both Qatargas and RasGas for LNG export. This amounts to savings of approximately 0.6 MTA of LNG or the gas equivalent of 29 Billion Standard Cubic Feet (BSCF), which is enough natural gas to power 300,000 homes. In terms of GHG emissions, the above offset equates to approximately 1.6 million tonnes of CO$_2$ per annum. As depicted in Figure 10 below, Qatargas Jetty flaring was reduced by 20% in 2014 and by nearly 90% in 2015 from 2011 baseline.

**Figure 10: Qatargas JBOG Flaring 2011-2015**

**QG2, QG3&4 Purge Gas Reduction Project**

Qatargas conducted a Flare Reduction Feasibility Study in 2011 to identify technically feasible options for flare minimization at the mega-trains. One of the most feasible and practical opportunities identified was purge gas reduction which represents almost 22% of all flaring at the mega-trains (detailed at Figure 4). Purge gas flows are an essential requirement to prevent air ingress into the flare system, however their rate can be optimized to industry recommended standards through engineering analysis. Significant flare reduction can be realized with a relatively small investment and accelerated timeframe.

Current purge gas at the mega-trains comprises the following streams:
• Header sweeping gas to prevent air ingress into the flare stack.
• ‘Burn back’ gas: purge gas introduced at the flare stack to prevent burn back at the flare tip, thereby increasing tip life.
• Flame shaping gas for utility flare tips (sour gas flare) to facilitate proper combustion at the non-steam assisted flare tips.

Normal operation purge gas flows are calculated based on the American Petroleum Institute (API) Standard 521 (Ref. 4) to provide less than 6% Oxygen (O$_2$), 25 feet from the top of the flare tip.

The Mega-Train Purge Gas Reduction Project was initiated in 2012 to realize the following main objectives:

1. Reduction in purge rates to API 521 levels in two phases for a total projected reduction of more than 60% (from 2012 purge rates):
   • Phase 1 – Dry Gas Flare #2 (DGF-2): A reduction of approximately 1.8 MMSCFD was realized in 2012 for QG2 DGF-2. A similar reduction was achieved for QG3&4 DGF-2 in 2013.
   • Phase 2 – Dry Gas Flare #1 (DGF-1) and Wet Gas Flare (WGF): DGF-1 and WGF tips are both steam assisted. The project approach is to use the steam assisted tips and flare stack steam (center steam) for burn back protection rather than fuel gas. Header purge can then be reduced to API 521 levels*.
   * No changes envisioned for sour gas flare due to its non-steam assisted flare tip and hazardous nature of sour gas.

2. Emergency Purge Gas:
   • Installation of an emergency purge gas system on dry and wet gas headers to address possible gas shrinkage during hot releases which may result in air ingress into the flare stacks.
   • 128 skin temperature sensors installed at 32 flare points around the mega-trains.
   • Emergency purge flow triggers if the difference between flare point (skin) temperature and ambient temperature increases beyond a set limit.

The Mega-Train Purge Gas Reduction Project was completed in 4th Quarter of 2013 and has reduced the purge gas flaring by approximately 45%.

**QG2, QG3&4 Flare Reduction Project**

In addition to purge gas reduction, the Feasibility Study completed by Qatargas in 2011 also identified a range of longer-term flare reduction opportunities for the mega-trains. These were further analyzed and shortlisted based on their technical feasibility, practicality and expected magnitude of flare reduction. A dedicated Flare Reduction Project was then initiated in 2013 to implement these opportunities. An overview of the identified opportunities with the highest flare reduction potential is provided in Table 1 below.

<table>
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<tr>
<th>Flare Reduction Opportunity</th>
<th>Scope of Work</th>
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Table 1: QG2, QG3&4 Flare Reduction Project - Main Opportunities
### Feed Gas Interconnection (Crossover)
- Interconnection available between Inlet Reception (IR) facilities for QG2 and QG3&4. Currently uni-directional from QG3&4 to QG2.
- Upgrade to bi-directional.
- Existing interconnection can be used to avoid depressurization of offshore pipelines during start-up of either asset thus minimizing flaring.

### Offspec Gas Recycle
- Recycle offspec gas from train undergoing trip, shutdown or restart to running train within same asset or mega-train in other asset.
- Majority of flaring following trip or shutdown occurs during train restart.
- Existing bi-directional line available between Unit 02 (AGR) of each mega-train (see Figure 11). Used for flare reduction in the event of hot section trip or full train restart.
- Upgrade existing bi-directional line to link Unit 03 (Dehydration, Mercury and Mercaptans Removal) and Unit 04 (NGL Recovery).
- Install new inter-asset header to recover across QG2 and QG3&4.

### Summary
A summary of Qatargas’ flaring performance is provided in Figure 11 below. The JBOG, Mega-Train Purge Gas Reduction Projects and operational initiatives for routine and turnaround flaring have progressively reduced overall flaring by approximately 70% between 2011-2015.
The contribution of flaring to overall Greenhouse Gas (GHG) emissions from Qatargas’ facilities is shown graphically in Figure 12 below. Flaring contribution to overall GHG emissions is reduced from 14% in 2011 to 4% in 2015.

Figure 12: Flaring Contribution to Overall Qatargas GHG Emissions (2011 – 2015)

Conclusion

With operational source reduction initiatives, completion of flaring reduction projects and monitoring and accurate reporting of flaring inventories, Qatargas has successfully reduced flaring at its LNG facilities approximately 70% since 2011. Qatargas 2 and Qatargas 3&4 Flare Reduction Projects once operational are expected to further reduce Qatargas flaring.

Many challenges still exist with respect to flare minimization at Qatargas. These include maintaining internal awareness and focus on flare management, and meeting sustainable flaring targets. Upcoming focus areas will include improvement in flare meter reliability and availability, minimization of flaring sources such as passing valves through implementation of a valve monitoring program (using an acoustic meter), continued optimization of operational procedures to reduce flaring, and development and implementation of a comprehensive Flare Management System with specific, standardized policies and procedures.

References