2019 GASTECH CONFERENCE

17-19 SEPTEMBER 2019
HOUSTON, TEXAS, USA

Liquefied Natural Gas
Egyptian LNG

ELNG SUCCESS STORY
PLANT TURN DOWN RATIO

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ConocoPhillips
Liquefied Natural Gas

OPTIMIZED CASCADE PROCESS

AGENDA

I. Timeline of Events

- Low Feed Gas Supply
- Feed Gas Interruptions

II. Risk Realization

- BAHX Thermal Cycles
- Corrosion Under Insulation (CUI)
- LNG Loading and 8” Cooldown lines

III. Operational Challenges

- High Turndown Ratio Operation Mode
- Offline Plant Readiness
- High Shutdowns/Restarts Frequency

IV. Accomplishments

- Operational Excellence
- Strategy Financial Return

ConocoPhillips
Liquefied Natural Gas

OPTIMIZED CASCADE PROCESS

TIMELINE OF EVENTS

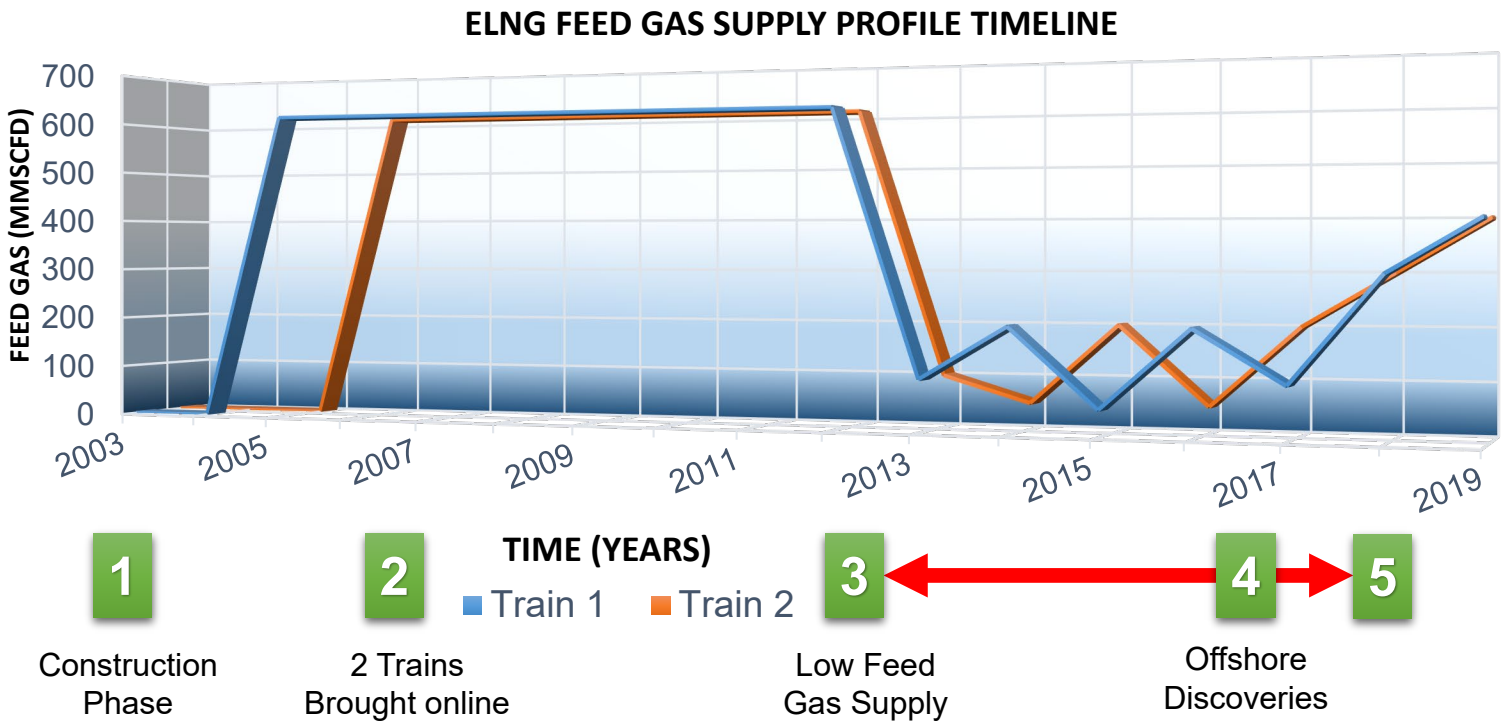
Egyptian LNG

- The Egyptian LNG facility is operated by Egyptian LNG (ELNG), consisting of two LNG trains owned by Shell, Petronas, EGas and Engie.

- Both trains utilize the ConocoPhillips Optimized Cascade® LNG process, each with design capacity of 3.6 MTPA.

- Each train was contractually designed to achieve 35% turndown of feed rates (around 225 MMSCFD)

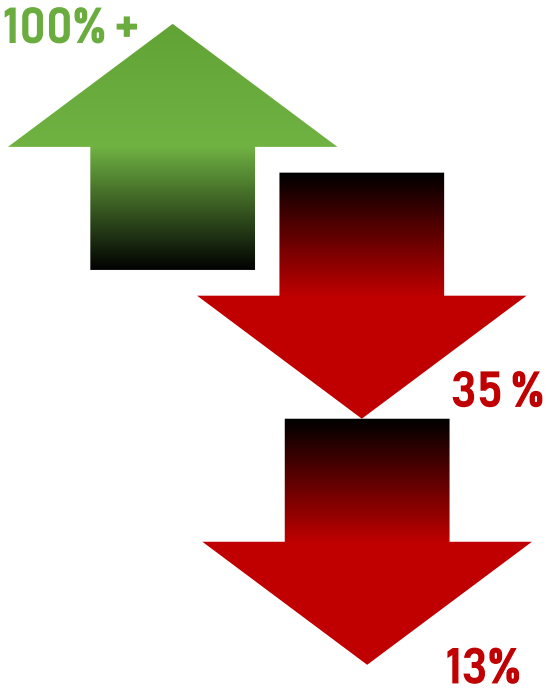
- By mid-2013 ELNG encountered severe supply limitations



CHALLENGES REALIZED

Egyptian LNG

- ELNG recognized a challenging opportunity if sustained operation at high turndown ratios could be realized for long periods
  - Ultimately achieved from mid-2013 to mid-2018
- ELNG succeeded in achieving turndown ratio of feed rates from the contractual 35% to as low as 13% (225 to 90 MMSCFD).
- Several key challenges were addressed.
- **Key challenges:**
  - Equipment & Piping Thermal Cycles
  - Equipment & Piping Corrosion under insulation (CUI)
  - LNG Loading & Cooldown Piping Thermal Cycles



BAHX Thermal Cycles

Egyptian LNG

- Two inevitable facts about BAHX exchangers are:
  - No definable endurance limits
  - Stresses are cumulative
- One advantage of the Optimized Cascade Process is that the adjacent pass-to-pass temperature profiles for most of the BAHXs passes are retained.
- ELNG experienced 60 feed gas interruptions between Jan-2014 to Dec-2016, each requiring shutdown and restart.
- Disruptions have the potential to impose unbalanced and cyclic thermal stresses on BAHXs, particularly while warming up from cold conditions or cooling down from warm conditions.
- ELNG was able to control exchanger temperatures within *The Standards of The Brazed Aluminium Plate-Fin Heat Exchanger Manufacturers' Association* (ALPEMA).

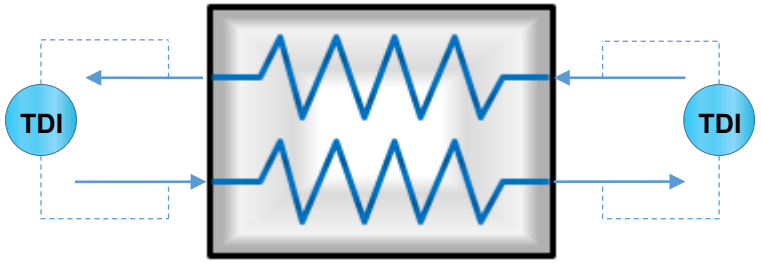


Illustration for Differential Temp during Feed Gas Variation for BAHX two adjacent passes

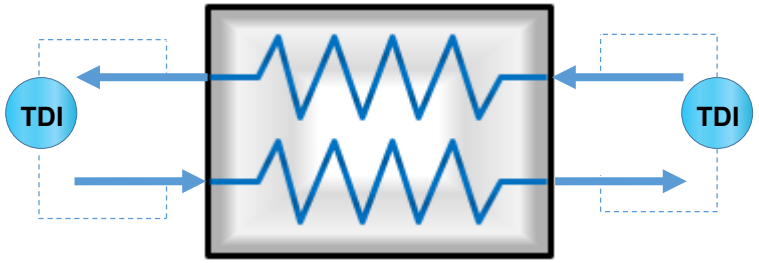


Illustration for Differential Temp during Feed Gas interruption for BAHX two adjacent passes

BAHX Thermal Cycles

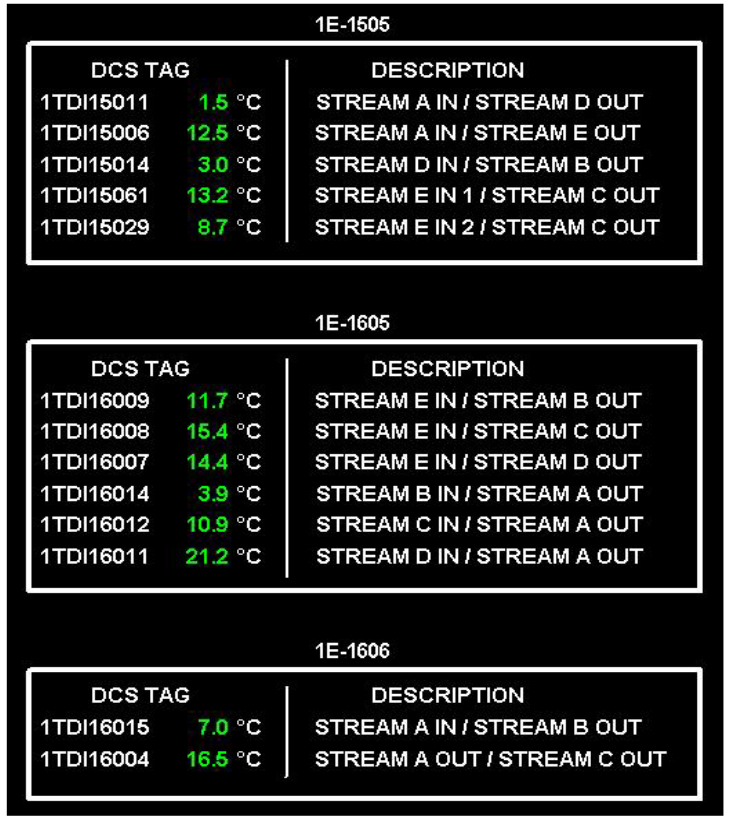
Egyptian LNG

- Two small BAHXs used as part of a heat integration scheme between fractionation columns within the heavy hydrocarbon removal system have proven problematic for ELNG due to the thermal stresses associated with sudden feed composition changes.
- ELNG and ConocoPhillips LNG Engineering performed a joint study to address through operational setpoint and procedural changes. Although reliability improved, the exchangers remain problematic.
- For the time being, the exchangers remain in service with longer term plans to replace.
- ConocoPhillips no longer utilizes BAHXs within heavy hydrocarbon removal systems.

BAHX Thermal Cycles

Egyptian LNG

- ELNG has addressed excessive BAHX thermal gradients through:
  - Configuring adjacent pass to pass temperatures alarms
  - Configuring temperature rate of change alarms
  - Revising the heavy hydrocarbon removal system start-up, shutdown, and operational procedures
  - Improving operator's competency through a continual training utilizing the Operator Training Simulator (OTS)



1E-1505

DCS TAG		DESCRIPTION
1TDI15011	1.5 °C	STREAM A IN / STREAM D OUT
1TDI15006	12.5 °C	STREAM A IN / STREAM E OUT
1TDI15014	3.0 °C	STREAM D IN / STREAM B OUT
1TDI15061	13.2 °C	STREAM E IN 1 / STREAM C OUT
1TDI15029	8.7 °C	STREAM E IN 2 / STREAM C OUT

1E-1605

DCS TAG		DESCRIPTION
1TDI16009	11.7 °C	STREAM E IN / STREAM B OUT
1TDI16008	15.4 °C	STREAM E IN / STREAM C OUT
1TDI16007	14.4 °C	STREAM E IN / STREAM D OUT
1TDI16014	3.9 °C	STREAM B IN / STREAM A OUT
1TDI16012	10.9 °C	STREAM C IN / STREAM A OUT
1TDI16011	21.2 °C	STREAM D IN / STREAM A OUT

1E-1606

DCS TAG		DESCRIPTION
1TDI16015	7.0 °C	STREAM A IN / STREAM B OUT
1TDI16004	16.5 °C	STREAM A OUT / STREAM C OUT

DCS Screen Image for monitoring Differential Temp between adjacent BAHX Passes

Corrosion Under Insulation (CUI)

Egyptian LNG

- CUI is external corrosion of piping and equipment underneath external insulation due water penetration that becomes trapped on the metal surface.
- CUI can remain undetected until the insulation is removed to inspect or worse when leaks occur.
- CUI generally occurs at metal temperatures between the freezing and boiling points of water.
- A broader temperature range is considered to account for different operational modes, temperature fluctuations, loss of insulation properties, and heat loss across equipment and longer piping runs.

Corrosion Under Insulation Example
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Corrosion Under Insulation (CUI)

Egyptian LNG

- A nice feature of the Optimized Cascade Process is that much of the cryogenic piping and equipment for the ethylene and methane refrigeration systems are contained within nitrogen purged cold boxes, which eliminates moisture and any associated CUI concerns.

- Propane refrigeration system piping and equipment is not included within a cold box and were identified as an area of concern for CUI.

- ELNG has addressed Corrosion Under Insulation by developing an inspection work plan for each equipment and piping item identified, based on the results a Risk Based Initiative (RBI) analysis.

LNG Loading and 8” Cooldown lines

Egyptian LNG

- The jetty loading and return lines can warm up during periods of significant downtime without some method of maintaining cold temperatures.

- The options are to:
  - Cool down every time a shipment is required
  - Maintain in a cold state.

- Both LNG trains at ELNG facility include 8” cool down lines, taken from the discharge of the LNG transfer pumps, to maintain the jetty loading line cold.

- The latter option is preferred to avoid excessive thermal cycling.

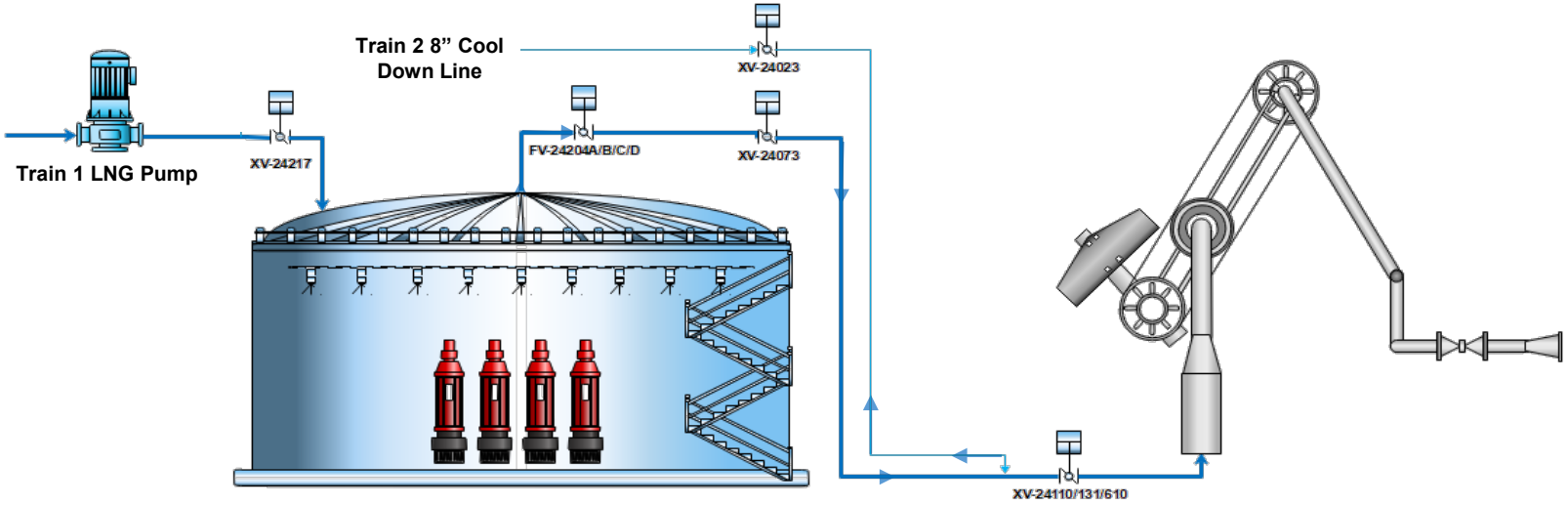
LNG Loading and 8” Cooldown lines

Egyptian LNG

- The normal method to maintain the jetty loading lines in a cold state is to cool using a slip stream from the LNG Transfer Pump discharge (from each train to the jetty loading arms).

- If an LNG train is offline, one of the LNG Loading Pumps may be used to maintain the LNG transfer line from either train in a cold state. During this time, the loading line isolation valves are isolated, and LNG reversed through the 8” cool down line to the respective transfer line, where it is then circulated back to the tanks.

- The 8” cooldown line is bidirectional, with the direction depending on whether or not the train is in service.

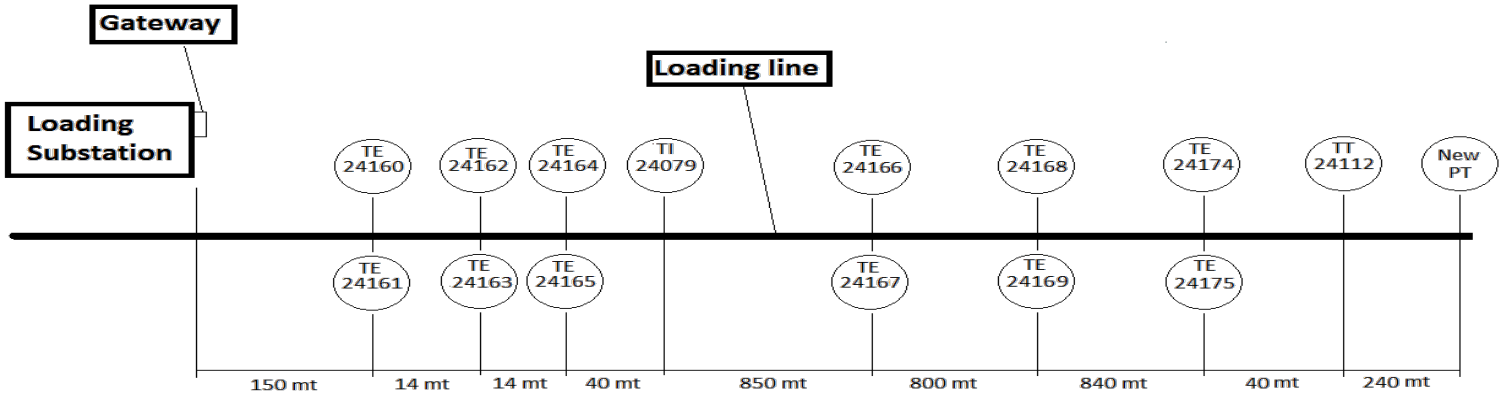


LNG Loading and 8” Cooldown lines

Egyptian LNG

- The 8” cool down lines were constructed using vacuum jacketed piping, for which multiple sections have failed to maintain vacuum, which presented an area of concern.

- ELNG outlined several actions to enhance the original design and ensure its reliability:
  - Additional Temperature Indication
  - An Additional Pressure Transmitter
  - Updated Instrumentation Systems
  - Updated Operational Procedures



Schematic of the additional Instrumentation for LNG Loading Line

Operational Challenges

Egyptian LNG

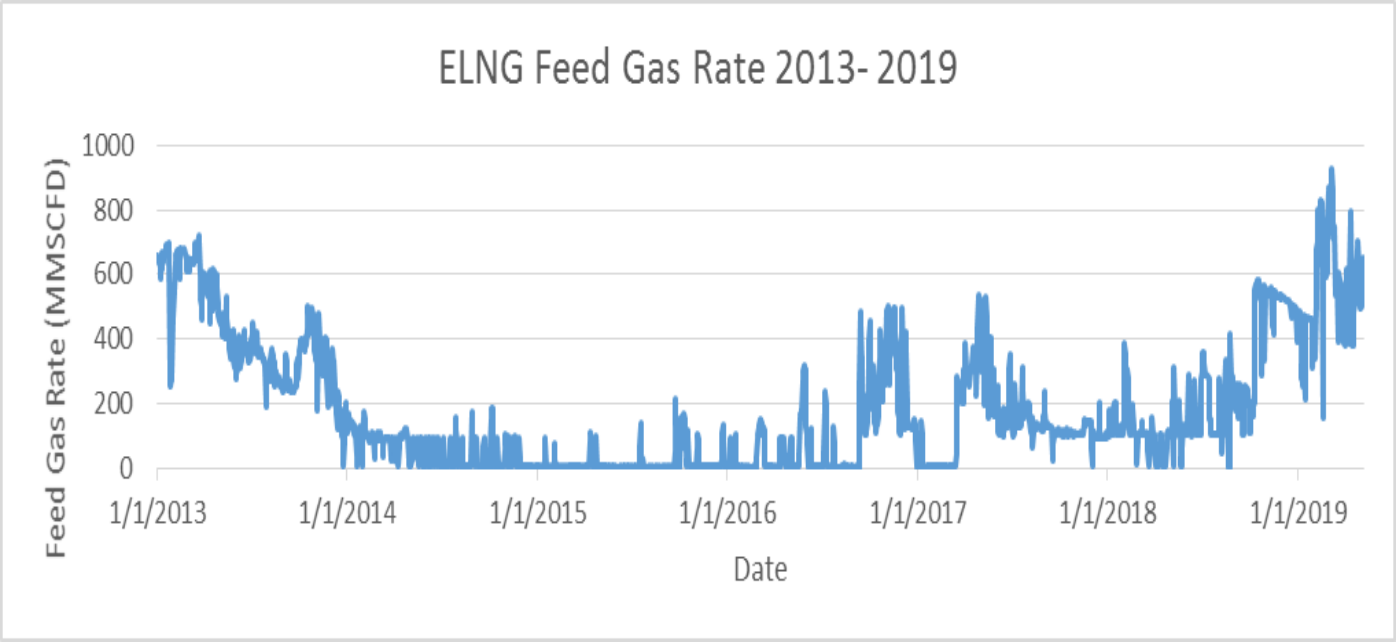
- Operational Challenges Addressed:
  - Plant readiness for the offline train
  - Operating and maintenance team competencies

- ELNG addressed those challenges by:
  - Developed and applied a Competency Assurance Management System (CAMS) maintain staff competency
  - Operator Training Simulator (OTS) to train both DCS and field operators
  - Detailed analysis report for each start-up with dedicated focus on cool down rates and BAHX adjacent pass differential temperatures
  - Deviations were highlighted and addressed with lessons learned applied to the procedures and training as part of a continual improvement process

OPERATIONAL CHALLENGES

Egyptian LNG

- Insufficient feed gas to sustain both trains at 13 to 15% of design feed gas rates.
- ELNG adopted a philosophy of maintaining one (1) train in operation at high turndown and the other train offline, switching between trains every two (2) months.
- The online train provided cooling for both the jetty loading lines as well as offline train transfer line.



ACCOMPLISHMENTS

Egyptian LNG

- **Strategic Targets:**
  - Minimize excessive thermal cycling
  - Minimize CUI concerns.
- **Applicability:**
  - Maintain cold conditions and operating levels within the cold boxes for long periods
  - Ability to easily and rapidly restart the Optimized Cascade process
- **Results:**
  - Integrity of both trains maintained
  - Maintenance costs minimized
  - All operational and maintenance staffing maintained
  - Operational training for the ELNG staff maintained
  - Positive Financial Returns

COMMERCIAL CONSIDERATIONS

Egyptian LNG

- Turndown between 13 and 15% of design feed gas rates from mid-2013 to mid-2018 provided the following commercial results
  - 705 on-stream days
  - 3.1 MM cubic meters of LNG production
  - 21 LNG cargoes (equivalent of approximately $354 MM)
  - Full operational and maintenance staffing and associated competencies maintained
  - Both ELNG trains maintained in operational readiness state until the production ramp-up in mid-2018

WRAP UP

Egyptian LNG

Questions ?

Thank You