A Focus On Balance

A Novel Approach Taking the Phillips Optimized Cascade LNG Process Into the Future

Prepared for AIChE Spring National Meeting
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LNG I – Operation and Reliability
Introduction

Setting the Perspective

Current Phillips Optimized Cascade LNG Process

An Alternate Approach

Furthering The Approach

Conclusions
Introduction

- Variables To Balance -

- Variables
  - CAPEX
  - OPEX
    - Availability, Reliability, Maintainability, Production Efficiency, Onstream Factor, Capacity Factor
    - Thermal Efficiency
  - Schedule

- Analysis
  - Life Cycle Cost
    - RAM Analysis
  - NPV

- More Difficult Concepts
  - Process Stability, Process Flexibility, Historical Deviation(s)
Introduction

- Defining the Variables -

- **CAPEX**
  - Include Entire Integrated Facility
    - Battery Limit Through Storage & Loading, Including Utilities
  - Total Installed Cost Basis - Exclude Owner’s Cost

- Thermal Efficiency
  - \((\text{HHV Products})/(\text{HHV Feed}) \times 100\)
  - All Products
  - Entire Facility Including Offsites & Utilities

- **RAM Results**
  - Life Cycle Basis
  - Entire Facility Including Offsites & Utilities
- Availability (Up Time/Total Time)
  - Calculation: $\frac{MTTF}{MTTF + MTTR + \text{Mean Logistics Delay}} \times 100$
  - Useful for Comparing Total Downtime of Various Options, Critical Sparing Philosophy, and Other Downtime Related Variables

- Production Efficiency
  - Calculation: $(\text{Predicted Prod}/\text{Required Prod}) \times 100$
  - Useful for Life Cycle Cost Analysis
  - More Appropriate Measure of LNG Produced

- Predicted -vs- Achieved
  - Should Be Able to Reconcile
Introduction - Balancing the Variables -

- Iterative Economic Solution
  - Multiple Options
  - Simultaneous Marketing Analysis
  - Environmental Impact Development
  - Mechanical Design Specifications
  - Equipment Vendor Alliances & Preferences
  - Management, Operations, Rotating Machinery Preferences
  - Schedule Changes

- Flexible & Economical Solutions Are Highly Desirable
  - Technology Licensor’s Task is to Monitor and Anticipate Industry Needs and Develop Flexible & Competitive Solutions
Historical & Current Overview of Technology In Consideration
Setting the Perspective
- Early Phillips Optimized Cascade Process -

Feed Gas

Gas Conditioning

Propane Refrigerant

Ethylene Refrigerant

Methane Refrigerant

LIQUEFACTION

Fuel Gas Compressor

LNG Storage

Marine Facilities

LNG Shipping

Plant Fuel
Setting The Perspective
- Improvements Over Early Design -

- Elimination of Fuel Gas Compression
- Heavies Removal Integration
- Improved Heat Integration
- Optimized Cold Box Configuration
- Improved Plant Layout and Constructability
- Open Loop Methane Cycle
  - Reduction in Vessels & Exchangers
  - Balanced Power Requirements Between Refrigerant Cycles
  - Optimal Compressor Staging
Setting The Perspective
- Current Simplified Block Flow Schematic -

Feed

Gas Conditioning
Propane Refrigerant
Ethylene Refrigerant
Methane Refrigerant

LIQUEFACTION & LPG RECOVERY

LPG Product(s)
Condensate

Fuel Gas Distribution
Plant Fuel

Vapor Recovery

LNG Storage and Loading

Marine Facilities

LPG Fractionation

LNG Shipping

Fuel Gas Distribution

Ship Vapors
**Setting The Perspective**

- **Simplified Driver Configuration**

  - **Gas Conditioning** 100%
  - **Propane Cycle** 100%
  - **Ethylene Cycle** 100%
  - **Methane Cycle** 100%
  - **Storage & Loading** 100%

  - **T/C 50%**

**Operational Specifications**

- **Overall Plant Availability**
  - Kenai – Over 33 Years Operation
  - Atlantic – Over 4 Years Operation

- **Operational Flexibility**
  - Full Rate 80 - 105%
  - One T/C Down 60 – 80%
  - Half Rate 30 – 60%
  - Idle 0 – 30%

>95%
Setting The Perspective - Typical Balancing Act Results -

- **CAPEX**
  - Grass Roots ~ $200-250/MTPA
  - Multiple Trains < $200/MTPA
  - < 3% Contract Variations
  - Under Budget

- **Schedule**
  - All Projects Ahead of EPC Schedule

- **Thermal Efficiency**
  - Up to and Over 93%

- **Availability**
  - ~ 98% and Over

- **Production Efficiency**
  - ~ 95% and Over

- **Capacity Factor**
  - > 1 (Achieved Production > Design Production)
Setting The Perspective
- Atlantic LNG Facilities -
Setting The Perspective
- Egyptian LNG Project -
Setting The Perspective
- Darwin LNG Project -
An Alternate Approach

Minimize Gas Turbines and Integrate Waste Heat Recovery
An Alternate Approach
- Single Turbines & Waste Heat Recovery -
An Alternate Approach
- Basis For Study -

- Study Performed Using PDC
  - LNG Product Development Center

- Base Case
  - Atlantic Train 2 Conditions
  - Feed and Ambient Conditions Fairly Typical

- Multiple Driver/Compressor Configurations
  - Compared Against Base Case
An Alternate Approach: Balancing Act Result Positives

- CAPEX: \( \sim \$200/\text{MTPA} \) (For Case Studied)
- Schedule: Assume Accurate EPC Schedule
- Thermal Efficiency: 93+%
- Production Efficiency: \( \sim 93\% \)
- Capacity Factor: Assume > 1 (Predicted Production > Design Production)
An Alternate Approach - Balancing Act Result Negatives -

- Decreased Process Flexibility
  - No Two-Train-In-One Reliability
  - Complicated Steam System
  - Single Shaft Turbines
    - Loss of Speed Control
    - Longer Startup Sequence
    - Low Compressor Case Pressure Required for Startup

- Note 1: Supplemental power held at only that necessary to overcome compressor system starting torque requirements.

- Note 2: No vapor or liquid expanders included anywhere in the facility.
Rebalancing the Variables

Minimize Gas Turbines, Integrate Waste Heat Recovery & Maintain Historical “Two-Train-In-One” Reliability
Furthering The Approach
- Add “Two Train In One” Reliability -
Furthering The Approach - Balancing Act Result Positives -

- **CAPEX**
  - Marginal Increase over Alternate Approach Above
  - ~ $200/MTPA (For Case Studied)
  - ~ 16% Decrease on TDC Basis From Base Case

- **Schedule**
  - Assume Accurate EPC Schedule

- **Thermal Efficiency**
  - 93+% 

- **Production Efficiency**
  - ~ 95% As Compared to ~ 93%

- **Capacity Factor**
  - Assume > 1 (Predicted Production > Design Production)
Furthering The Approach  
- Balancing Act Result Negatives -

- Decreased Flexibility Over Multiple Dual Shaft Turbine Designs
  - Complicated Steam System But With Higher Reliability
  - Single Shaft Turbines
    - Loss of Speed Control
    - Longer Startup Sequence
    - Low Compressor Case Pressure Required for Startup

- Note 1: Supplemental power held at only that necessary to overcome compressor system starting torque requirements.

- Note 2: No vapor or liquid expanders included anywhere in the facility.
Conclusions

- Cost Competitive, Flexible Solution With Waste Heat Integration

- Configuration Using GE Frame 7EA’s
  - For Feed Conditions Considered, Applicable From 3.5 to 5.5 MTPA
    • No Power Augmentation Other Than Starting Torque Requirements Considered & No Vapor Or Liquid Expanders Considered.

- Configuration Using GE Frame 9E’s
  - For Feed Conditions Considered, Applicable Up to 6.5+ MTPA
    • No Power Augmentation Other Than Starting Torque Requirements Considered & No Vapor Or Liquid Expanders Considered.
Conclusions - Continued

- Environmentally Friendly Option
  - Less Point Sources for Emissions
  - Recovery of Thermal Energy

- Advantages Over Cogeneration Options
  - Large Electrical Motors Are Not Required
  - No Complicated Electrical Distribution
  - Power Directly Coupled to Refrigeration Shaft

- Easily Expandable Configuration
  - Example: Three Gas Turbines With Three or Perhaps Two Larger Steam Turbines
THANK YOU