LARGE LNG TRAINS: DEVELOPING THE OPTIMAL PROCESS CYCLE

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Overview

- Evolution of increasing train capacity
- Optimizing LNG liquefaction cycles
- Applicability to large trains
  - maximize use of proven equipment
  - maximize production
  - minimize cost and risk
Process Cycle Development

- **Design Basis**
  - Project Requirements:
    - Process Reliability / Flexibility
    - Environmental Economic Drivers / Compressors

- **Process Flow Scheme**
- **Simulation & Optimization**
  - Customized Engineering Models for Major Equipment (e.g., Compressors)
  - Main Heat Exchanger

- **Cycle Analysis**
- **Exergy Analysis**
- **Process Design Package**
Complexity of Optimizing LNG Liquefaction Cycles

- 20-50 variables to optimize (e.g. temperatures, pressures, compositions, flows)
- Over 50 constraints (e.g. compressor aerodynamic criteria)
- Typical numerical optimization techniques are inadequate
- Parametric studies are time-consuming

![Graph showing the relationship between number of variables and number of simulations. The graph indicates an exponential increase in the number of simulations required as the number of variables increases.](image-url)
Two Variable Parametric Study

Parametric study simulations
Two Variable Parametric Study

- Minimum specific power determined by sophisticated optimization techniques
- Parametric study simulations
Sophisticated Optimization Tools

- Specialized optimization tools and techniques developed in-house
- Amenable to processes with many inter-dependent variables & constraints
- Finds optimum more easily & accurately
- Less time spent on computer optimization
- More time available for cycle analysis
- Incorporates economic information
Customized Engineering Models

- Developed specifically for major equipment
- Incorporated into simulator
- Based on actual design criteria & field/test data
- Insure a realistic design

Models developed for:
- Refrigerant Compressors
- Main Cryogenic Heat Exchanger
ICEC™ Refrigerant Compressor Model

- Based on actual data
- Accurately predicts compressor efficiency
- Minimizes time consuming iterations with compressor manufacturers
- Insures an optimum design on the first pass
Refrigerant Compressors

Feasible Operating Region

Increasing Mach Number (M)

Increasing Inlet Flow Coefficient (IFC)

Constraint: Max Mach Number

Constraint: Max Inlet Flow Coefficient

Increasing Production

Constraint: \( M = f(\text{IFC}) \)
Wound Coil Main Exchanger

- Impacts efficiency and LNG production
- Liquefies & subcools natural gas
- Accurate prediction of heat transfer and pressure drop
Main Exchanger Models

**WCHTEX**
- Incorporates impact of internal geometry on performance
- Allows exchanger to be optimized for project requirements

**WZONE**
- Develops mechanical specifications from process specifications
- Provides for a smooth interface between process and mechanical designs
Exergy

- Useful for evaluating/improving LNG cycles
- Identifies impact of equipment on efficiency
- Shows where improvements are most beneficial
- Exergy = H – T_0S
Lost Work

- Excess work due to not being perfectly thermodynamically efficient
- \( \text{Lost Work} = \text{Exergy In} - \text{Exergy Out} + \text{Work} \)
- Used to determine contributions to total lost work
- Provides cost-benefits trade-offs
Components of Lost Work

Compressors and Turbomachinery
Pressure Drop, Mixing/Separating
Exchangers
Main Exchanger
Air Coolers
Pressure Letdown
Reducing Lost Work (Improving Efficiency)

$DT = \text{Propane Condenser Approach Temperature}$

Relative Specific Power vs. Relative Main Exchanger Area

Points:
- A (Base Point)
- B
- C
- DT
- DT-5°C
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**Process Flow Scheme**

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**Cycle Analysis**

**Process Design Package**

**Exergy Analysis**
AP-X™ Process

C3 Pre-Cooling

Mixed Refrigerant Liquefaction

Nitrogen Expander

LNG
Summary

- Sophisticated process design techniques required
- Economic information incorporated into the optimization process
- Permits maximum utilization of equipment

This technology driven approach is critical to providing more LNG at a lower cost
Thank you