Mass & Energy Balancing at LNG Receiving Terminals
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Outline

Mass & energy balancing at LNG receiving terminals
  – What?
  – Why?
  – How?
Mass & Energy Balancing

What?
Mass & Energy Balancing - Application Areas

- Custody transfer handling

- Inventory monitoring
  - Shipper/owner level
  - Tank composition tracking (overall and/or per tank)

- Energy consumption & losses
  - Shrinkage
  - Electrical power

- Instrumentation error identification

- Send-out Wobbe control

- Environmental monitoring
Energy Consumption & Losses

Gas
- Vaporizers (Open Rack vs. SCV or IFV)
- Flare
- Leaks or repairs

Electrical power
- Pumps
- Compressors
- Nitrogen production
- Etc.
LNG Terminal Process - Simplified Main Flows

- LNG Carrier
- N2 Production
- Compressor
- Re-Condenser
- LNG Tanks
- Grid Delivery
- Vaporizers

Flow connections shown with arrows and symbols.
Mass and Energy Balancing - Subjects to be Considered

- Main and minor flows (include or not)
- Measurements available
- Measurement accuracies
- Assumptions on composition
- Operating Modes of LNG Receiving Terminals (no loading!)
  - Unloading with send-out
  - Unloading without send-out
  - Send-out without unloading
  - Neither unloading or sending out
- # Units (simultaneously) used for operations
  - E.g. 2 tanks for unloading, 2 tanks for send-out, and recirculation between tanks
Mass & Energy Balancing
Why?
Interest in Mass & Energy Balancing (1)

- Both on liquefaction and receiving / regasification side

- Changing LNG business
  - Spot
  - Cargo trades
  - Open contracts

- Multi-user terminals
  - Dedicated with TPA
  - Merchant
Interest in Mass & Energy Balancing (2)

- Potentially interested parties
  - Shippers (buyers) / terminal users
  - Suppliers (sellers)
  - Terminal operators
  - Society represented by authorities (regulatory compliance)

- Depending on contract type
  - Incoterms

- Contractual arrangements
  - Terminal Access Code
  - Individual throughput agreements
Net energy amount available to shipper =
Delivered energy amount (carrier unload)
– Shrinkage (in terminal)
± Inventory corrections (by operator)
Mass & Energy Balancing

How?
Measurement @ LNG Terminals

- Location of measurements
- Quality/accuracy
  - Importance of accuracy based on time line of the purpose (daily, weekly, monthly, annual).
    Level measurement most accurate over long period of time
  - Relative error introduced by measurement errors of different devices (e.g. LNG vs gas)
  - Variance in accuracy depending on the state of the terminal at the beginning and end of the (un)loading job (e.g. related to temperature influences on strapping tables)
- Redundancy of measurements
  - Option to use ship readings and integrate these data in a reconciled mass balance
- Timing of (un)loading measurements
  - Accuracy in starts/stops of (un)loading phases
How Mass & Energy Balancing

- Manual

- Dedicated IT solution for unloading cross-check (Japan)

- Spreadsheet

- High level in commercial IT system

- Detailed in PIMS/MES system
High Level in Commercial IT System

- Prevailing method ?!
- Backed by contracts & agreed procedures
  - Terminal Access Codes
  - Individual contracts
- Unloaded energy amount calculations (simple)
- Built-in high-level reconciliation methods
- Manual interventions
  - Inventory / book stock changes
  - Shrinkage figure updates
Unloading monitoring
- Composition OK? i.e. cargo acceptable?
- Instrumentation OK? i.e. challenge capability for surveyor report
- Tracking of carrier unloading stages incl. interrupts (can also allow comparison of (un)loading occasions and/or aggregation of (un)loading occasions)
- Determine unloaded amount based on terminal operational status (challenge surveyor report)

Energy consumption monitoring

Loss monitoring

Flare monitoring

Environmental monitoring
Interpretation of the history data in terms of material properties, mass and energy flows, reconciliation

Interpretation and presentation of the history data in terms of non-continuous periods (batches)

The LNG Terminal
Data Historian / PI MS (Exaquantum)

- Data collection of (tag-based) time series data and Alarm & Event (A&E) data
  - Process data from PCS
  - Manual entries
  - Data from other systems

- Aggregations of time series data

- Calculations

- Graphical display of data, trends, etc.

- Reporting

- Export capability (e.g. Excel)
Exaquantum Batch @ LNG Receiving Terminals

- Automatic status-based batch-based collection of information for the LNG unloading process rather than retrospective batch analysis

- The different stages in the unloading process are tracked allowing even complicated (e.g. interrupted) unloading sequences to be handled

- Collected information can be made available to other applications e.g. to reconcile ship unloading records

- Comparison of different carrier unloads based on different properties (carrier, size, volume, etc.)

- Use of previous carrier data (metering error?)
The mPower Plant Model-based applications provide self-configuring management level reports based on data from history systems like PI MS, LI MS, logbooks, etc.

mPower models the physical plant with a software object structure that understands the key concepts of material location, plant connectivity and containment.

When this plant model is linked to the lower level data sources, it is simple to define any physical or time boundaries and then request reports based on them.
mPower: Plant Model Features

- Definition of Plant Objects
  - Sites, Plants, Units, Tanks, Streams

- Definition of Data Sources
  - Within mPower and to legacy software applications

- Physical Mapping of Plant Layout
  - Units and interconnections to Nodes and Streams

- Data Conversion to Information
  - Calculation and validation
Example Terminal Model
**Relevant mPower Functions**

- **Mass and Energy Balancing** to detect problems quickly when mass balancing shows an inconsistency
  - Leaks
  - Unauthorized removal of material
  - Instrumentation faults or failure

- **Data Reconciliation** to improve the quality of the process data used by mPower
  - Reports on instrumentation inaccuracies
  - Able to determine missing measurements to reduce the need for instrumentation
mPower: Possible LNG Terminal Functions

1. Collecting measurement information
2. Calculating mass and energy balances
3. Investigating faulty measurements
4. Reconciling redundant measurements discrepancies
5. Reconciling ship unloading records
6. Investigating excessive losses
7. Reporting end of period reconciliation
Purpose

- Online error check and warning/alarm (e.g. instrumentation failures)
- Unloaded amount
- Daily/Weekly/Monthly stock balance

Automatic vs. manual

Pre-defined vs user-definable (on the fly)

General reconciliation meanings
Reconciliation: Two Meanings

1. Adjustment of flows and inventories to values different from the raw measured values so as to achieve a balance (if acceptable)

2. Analysis of the flows and inventories so as to identify “lost” material
1. Adjusting values to achieve a balance

Reconciliation illustrations (1a)

\[ 10 \leftrightarrow 2 + 7 \]

Raw

10 \rightarrow 7

Adjusted

9.8 \rightarrow 7.9

\[ 9.8 = 1.9 + 7.9 \]
1. Adjusting values to achieve a balance

\[ 63 \leftrightarrow 20 + 40 \]

Raw:
- 20
- 40
- 63

Adjusted:
- 20.8
- 41.5
- 62.3

\[ 62.3 = 20.8 + 41.5 \]
2. Calculating loss

Raw: $10 + 2 = 2 + 7 + 1$

Adjusted: $10 = 2 + 7 + 1$
Conclusion
Mass and energy balancing at LNG receiving terminals is getting more attention.

The technology to do detailed, automated mass and energy balancing is available.

It makes more detailed and frequent mass & energy balances possible.
Thank you for your attention