Marine Technology and Standards Workshop
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Traceability of Marine LNG Bunkering Measurements

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Topics

- LNG Bunkering
- Bunkering sources
- Primary standards
- Traceability
- System design

Traditional LNG Applications

- First refrigeration system: 1873
- First commercial plant: 1917
- Peak shaving
- Pipeline transport alternative

Alternative to pipeline transport

LNG Bunkering

Bunkering

"the term bunker is generally applied to the storage of petroleum products in tanks, and the practice and business of refueling ships."

Originates from ship-board coal bunkers

First LNG fueled vessel, Glutra ferry, Norway, 2000

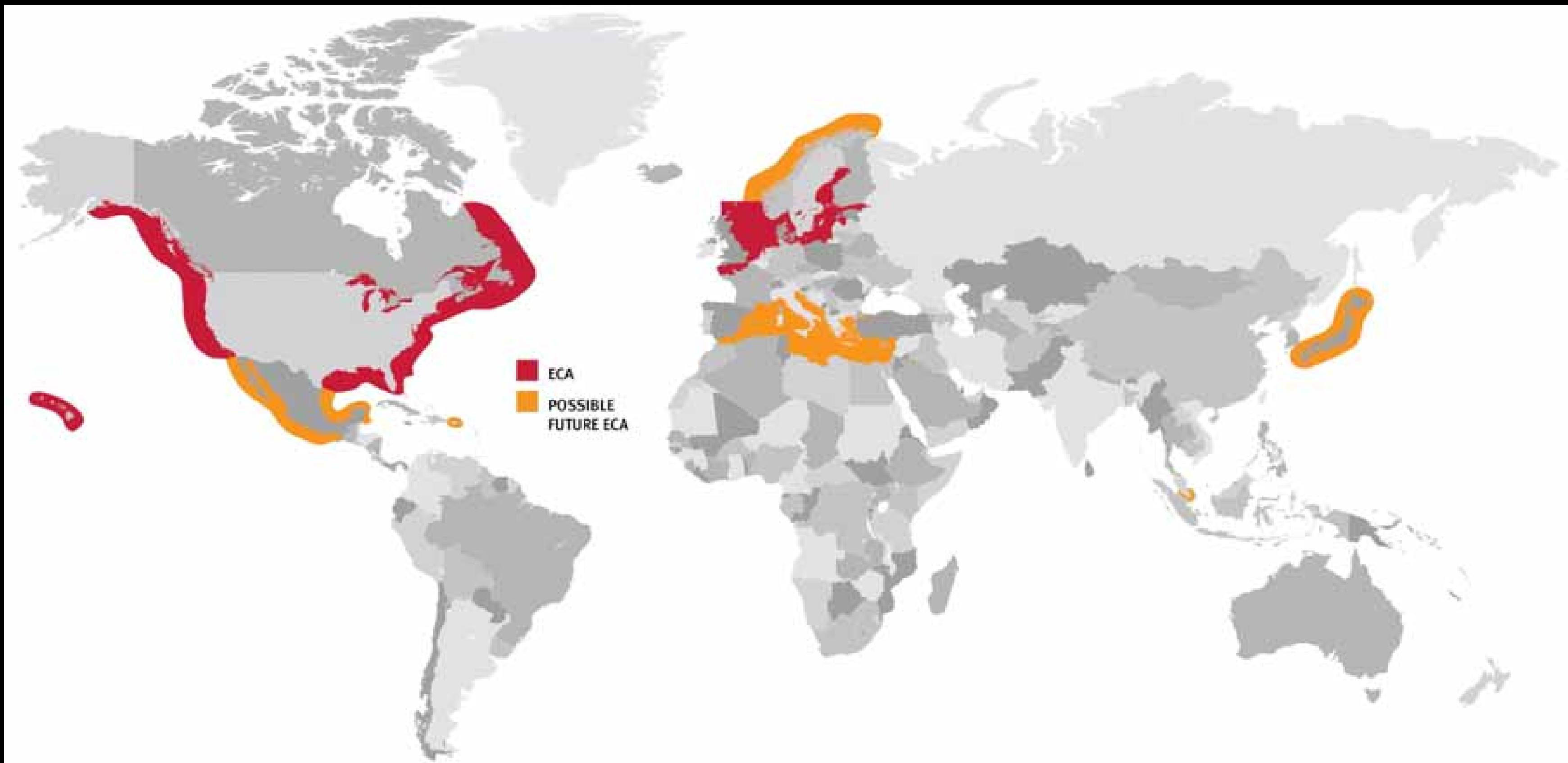
Marine Fuel LNG

- 2016: 77 vessels using LNG fuel, mostly in Norway
- 2022: 24 US (Jones Act) vessels

LNG Fuel Drivers

- Environmental regulation
- Cost and availability
- Geo-politics

Environmental Control Areas



ECA Solutions

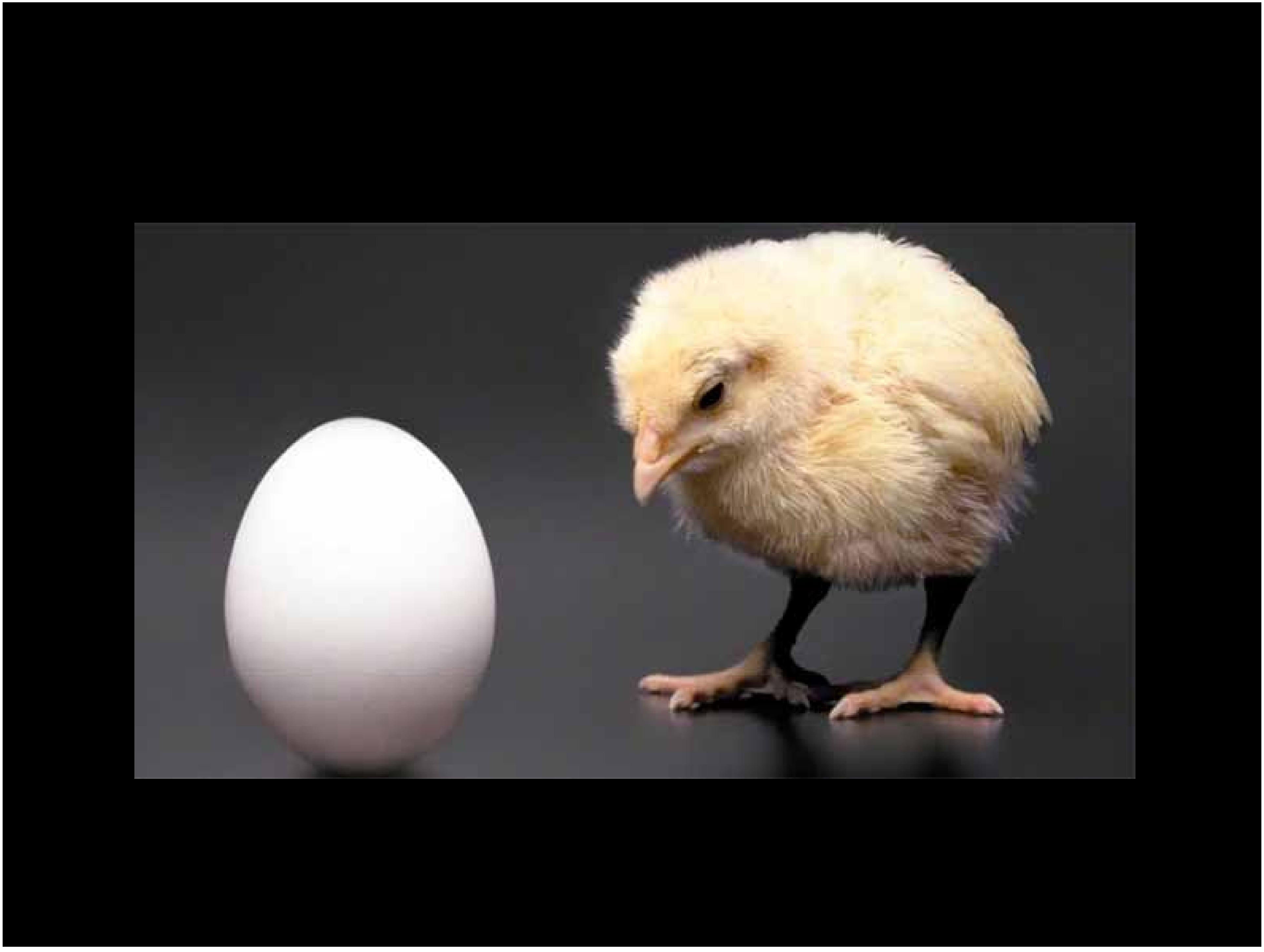
- Scrubber system to remove sulfur
- Dual fuel system, ECA vs non-ECA
- Natural gas fuel
- Natural gas/diesel fuel mixture

ECA Solutions

Likely requires LNG measurement

- Natural gas fuel
- Natural gas/diesel fuel mixture

Bunkering Sources



“Current” LNG Bunkering Sources

- Truck transfer (33%)
- Portable storage container (17%)
- Fixed storage tank (17%)
- Barge transfer (33%)
- Multi-drop truck transfer


LNG
中集圣达因制造

LNG Truck Bunkering

LNG Barge Bunkering

Portable Storage

"Current" LNG Bunkering Sources

Direct mass (static) traceability

- Truck transfer
- Portable storage container

Indirect mass (dynamic) traceability

- Fixed storage tank
- Barge transfer
- Multi-drop truck transfer

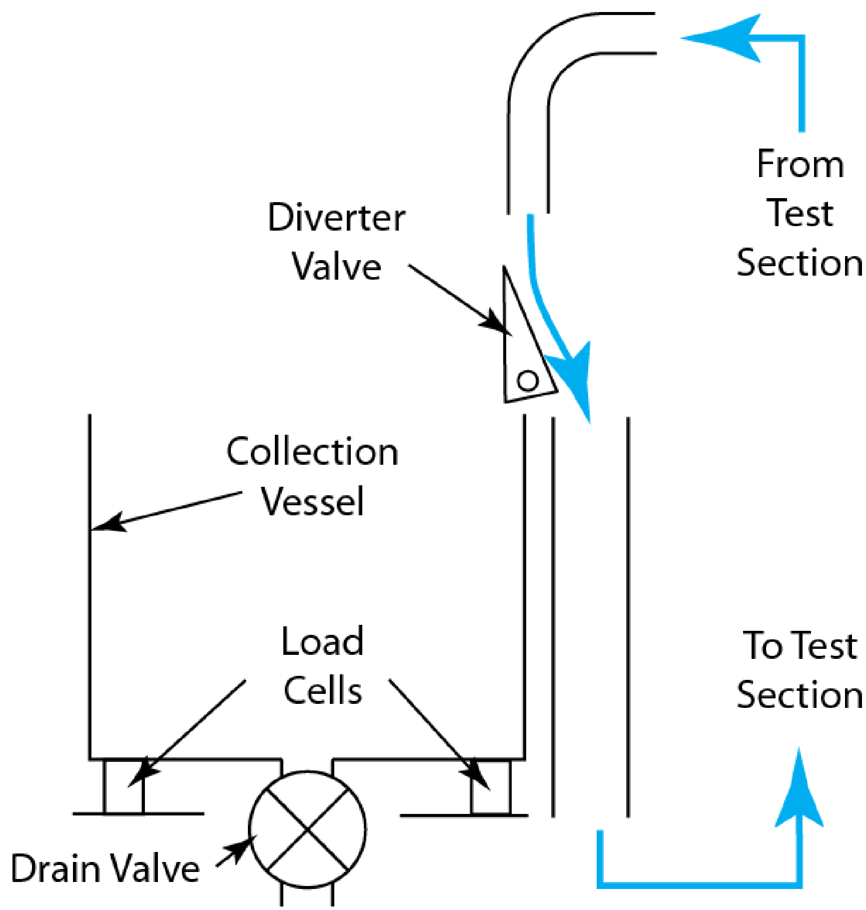
Small Scale LNG

Primary Standards

Primary Standards

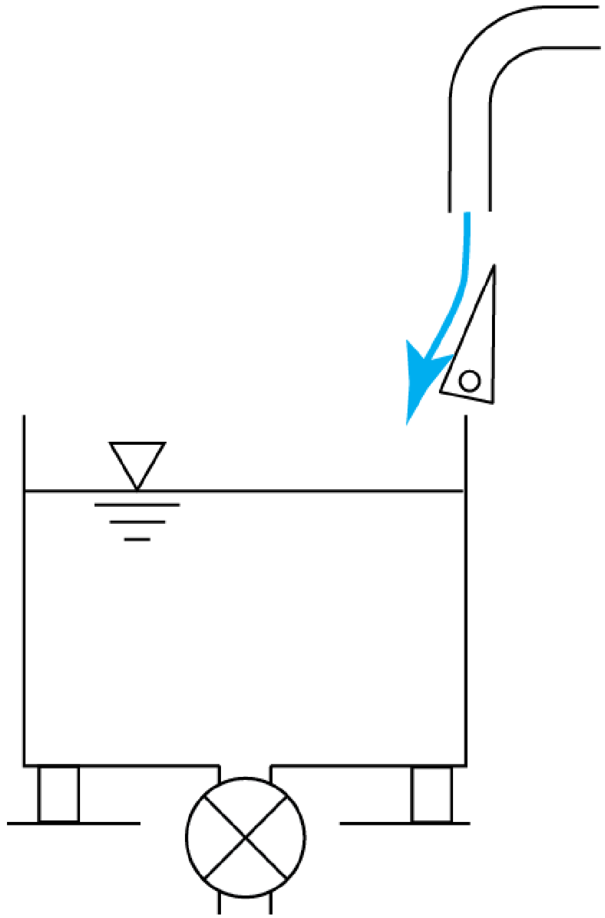
- Gravimetric vs volumetric
- Static vs dynamic

Static Gravimetric Standard



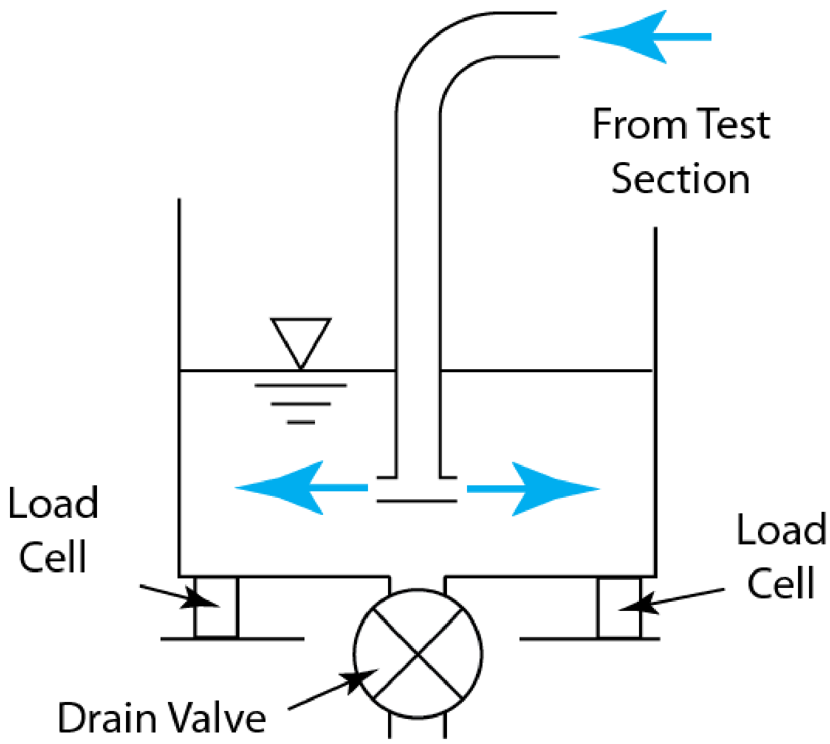
“Startup”
Operation

Static Gravimetric Standard

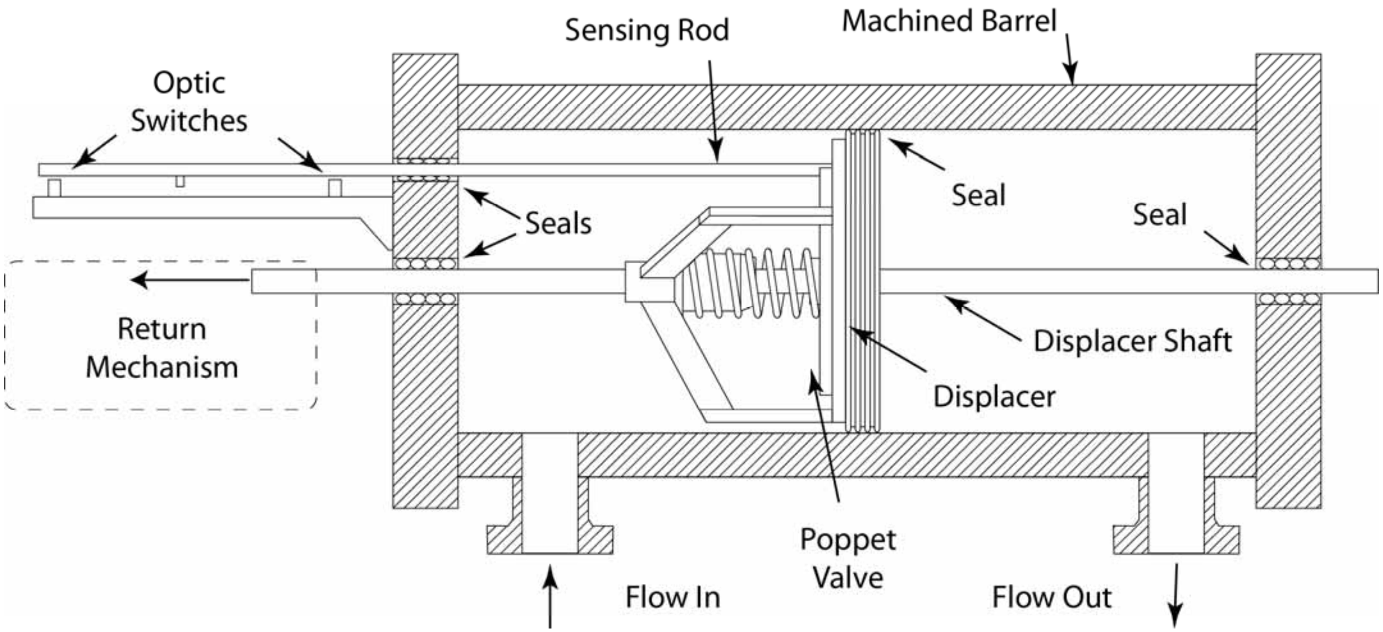


"Calibrate"
Operation

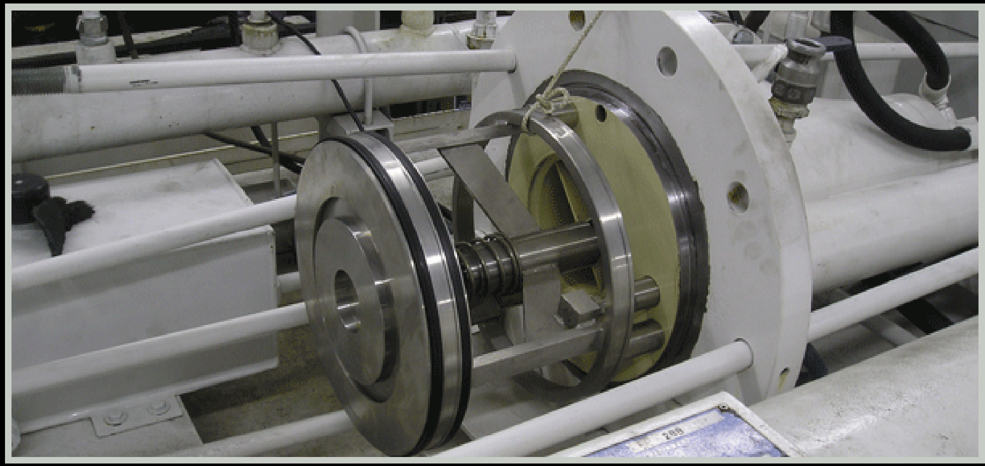
Dynamic Gravimetric Standard



Dynamic Volumetric Standard



Flow Provers



Static Volumetric Standards

Current Primary Standards

- NIST LN_2 System
- VSL LNG System
- Commercial cryogenic prover under field test

NIST System

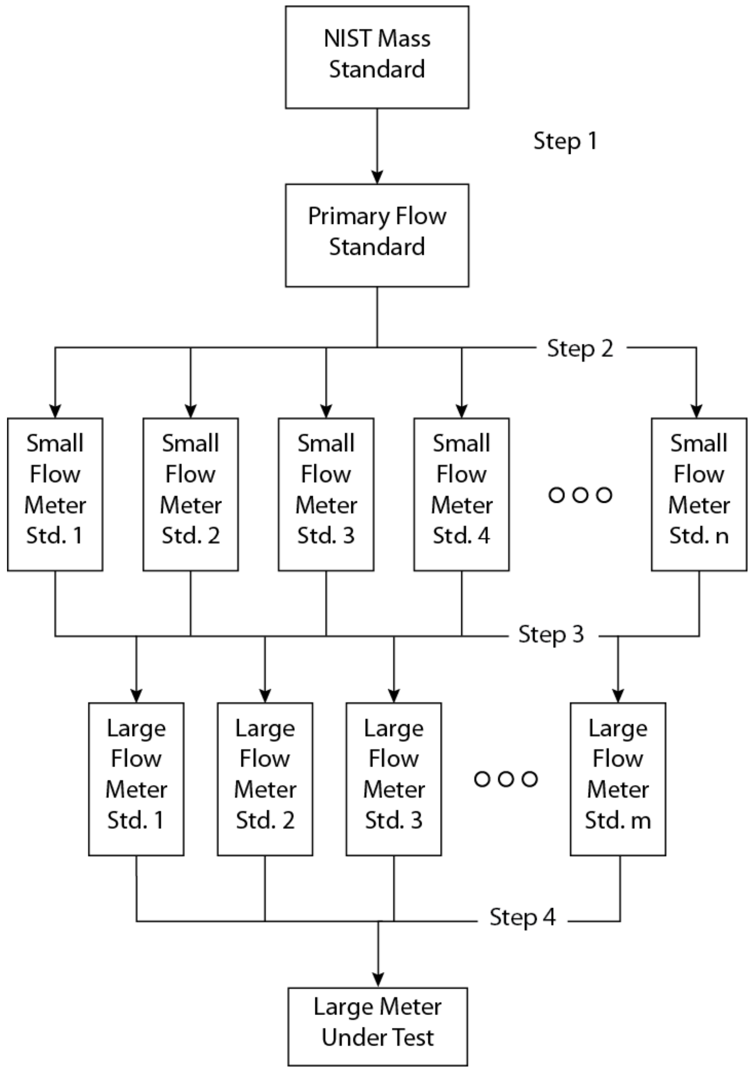
- Built in 1968
- Operates with liquid nitrogen
- Safer and less expensive than LNG
- Reynolds number overlap
- 1 – 10 kg/s, 0.5% uncertainty
- Dynamic gravimetric standard
- Operated by CEESI, owned by NIST

VSL System

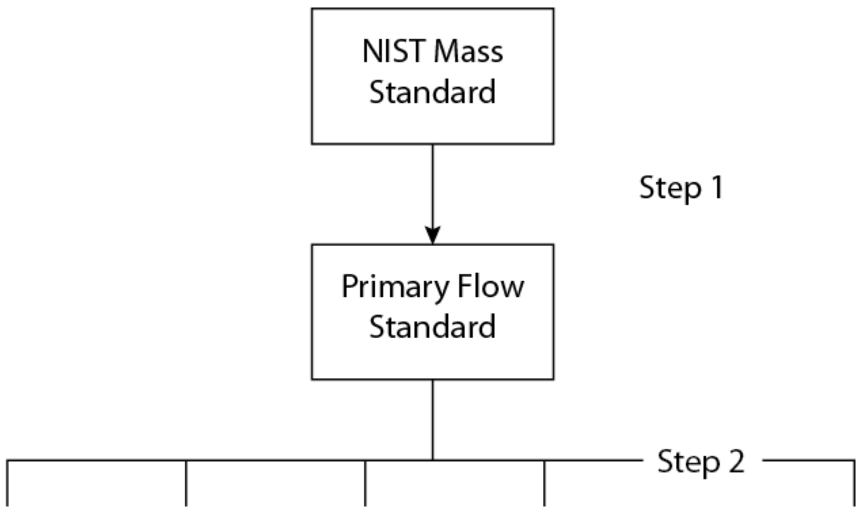
- VSL: Dutch national measurement institute
- Recently built (2010?)
- Operates with liquid natural gas
- 1.3 – 4.5 kg/s, 0.12 – 0.15% uncertainty
- Static gravimetric standard, inline 3-way diverter valve, no free jet

Traceability

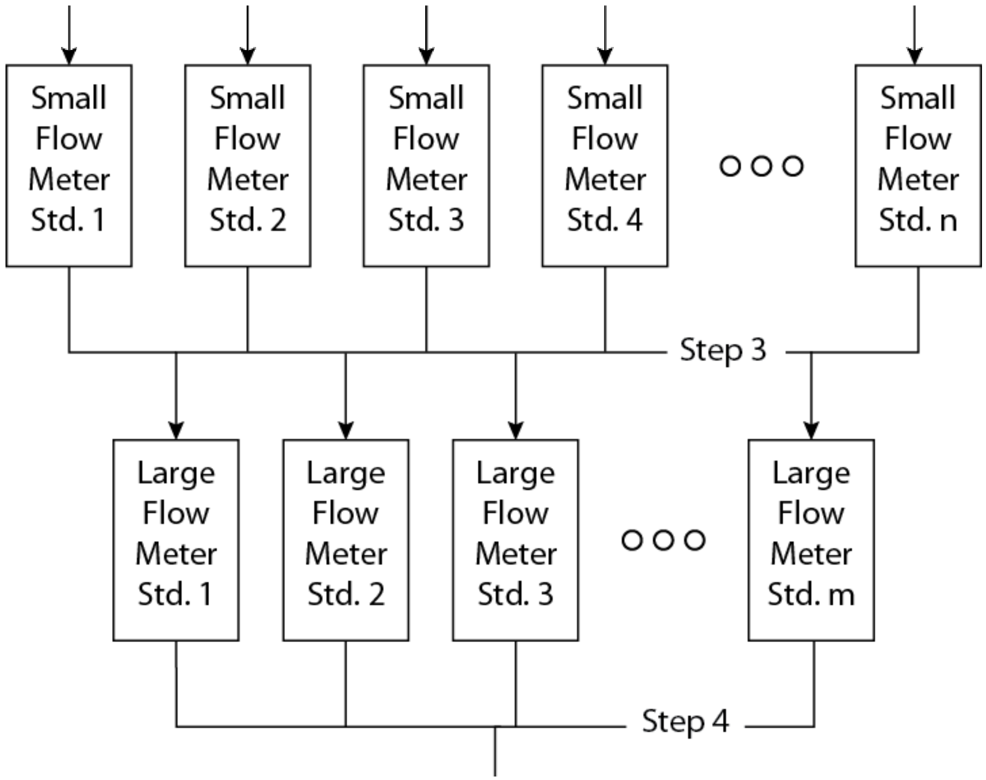
Typical Traceability



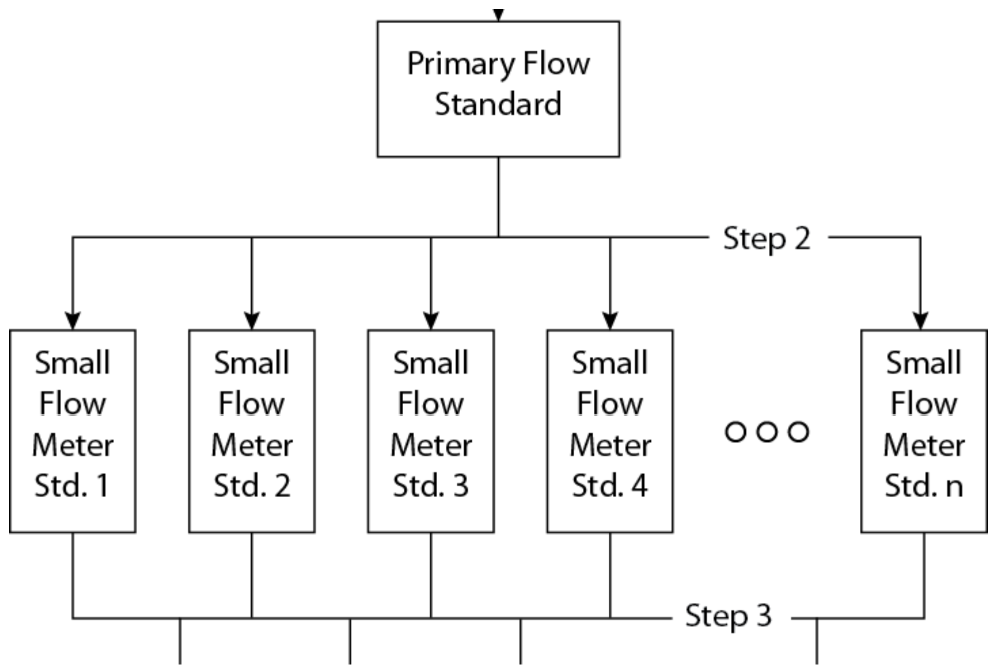
Typical Traceability



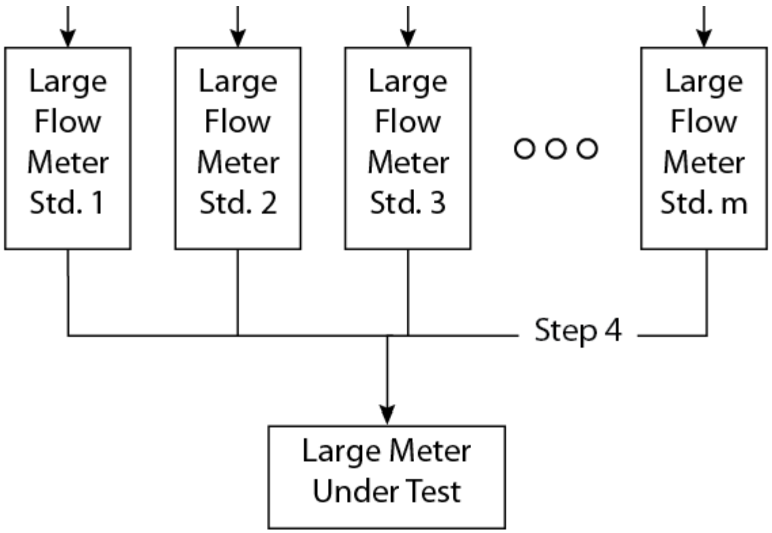
Typical Traceability



Typical Traceability



Typical Traceability



System Design

Flowmeter Consideration

- Turbine meters
  - Traditional cryogenic meters
- Newer technology
  - Coriolis, low flow
  - Ultrasonic, high flow
  - No moving parts
  - Mass vs volume
  - Pressure drop
  - Transient response

Density and Heating Value

- Varies with pressure, temperature, composition
- Requires sampling
- Requires state equation
- Can vary with time
  - boil of gas (BOG)
  - Multiple feeds into storage

Some Flowrates

Important for flowmeter range

- Highway truck refuel: 0.8 kg/s
- Bunkering barge: 1.1 kg/s
- LNG delivery truck pump: 0.3 – 1.8 kg/s
- Locomotive refuel: 14.6 kg/s
- Ferry terminal bunkering: 53 kg/s
- LNG carrier cargo load: 670 – 2000 kg/s

Some Uncertainties

Very rough estimates:

- 40 ft ISO container, mass discharge: 0.44%
- Smaller container, mass discharge: 0.81%
- LNG cargo volume: 0.20% - 0.54%
- LNG density: 0.46%
- NIST system: 0.5% (0.18% target)
- VSL system: 0.12% - 0.15% (0.10% target)

Summary

- Natural gas use is expanding
- Liquefaction is used for storage and transport
- Many LNG applications are new:
  - Measurement methods are under development
  - Direct vs indirect traceability to mass
  - We can learn from traditional flow measurement