cool to excel.

Use of Stirling Cryogenerators for on-site bio-LNG production

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DH Industries BV

- Based in Eindhoven, The Netherlands
- Successor of Philips Cryogenics, in business since 1955
- Main product brands:
  - Stirling Cryogenics:
    Several types of Cryogenerators to produce on site cooling power
  - CryoZone:
    Several types of pumps and circulators for cryogenic gases and liquids.

Topics

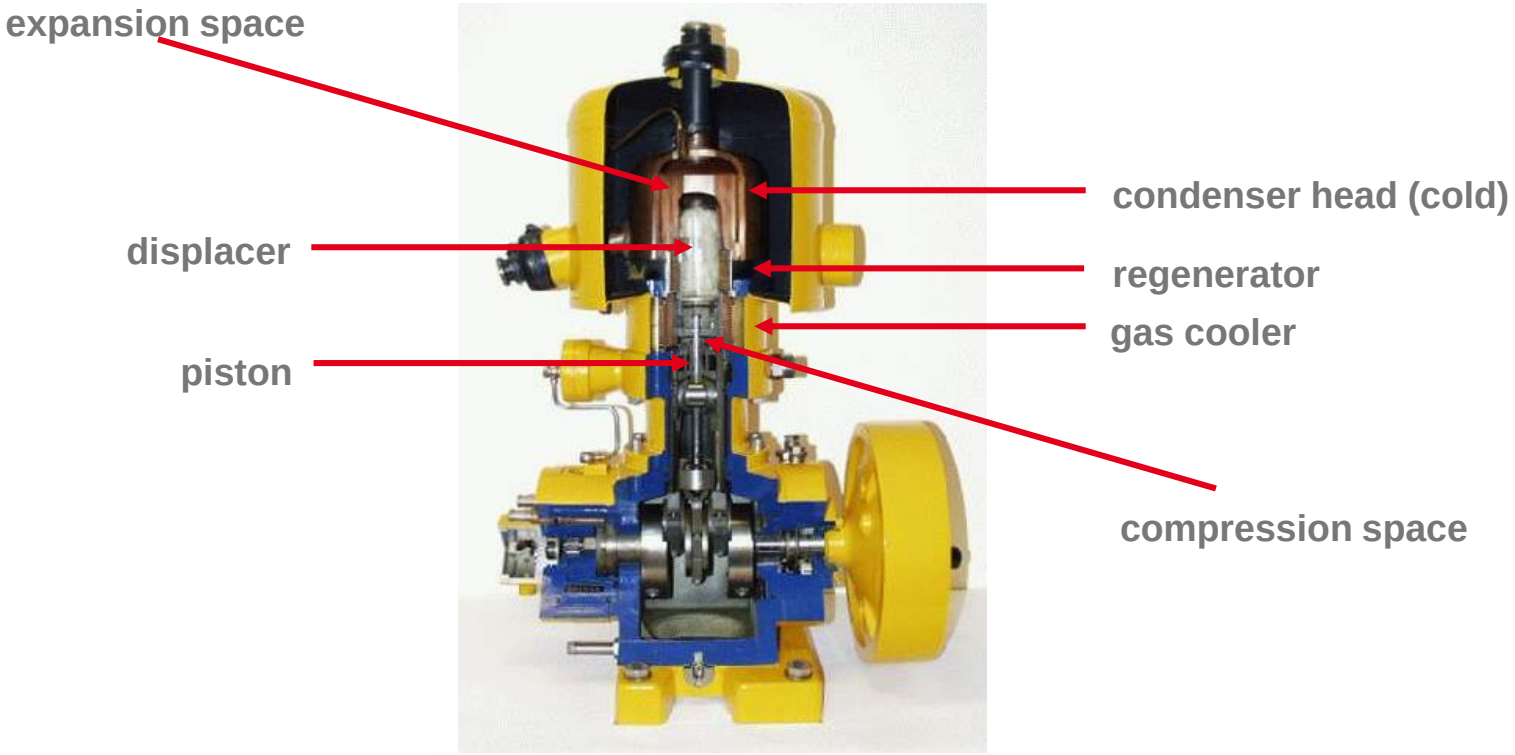
- How is on-site cooling power created?
  - The Stirling Cycle
- How to integrate liquefaction in a biogas installation?
  - How and where to integrate liquefaction.
- Why liquefaction of bio-methane?
  - How to (better) valorize your methane molecule
- Economics
  - Can liquefaction do this for you?

How is cooling power created? (1)

- Generally, all cooling is created by compression and expansion
  - Your fridge
  - Large cryogenic systems based on turbines (ASU's, LNG Algeria, Malaysia etc.)
  - Medium size turbine based systems like Cryostar
  - Nano, micro, small liquefaction systems based on Stirling Cycle Cryogenerators
- Which process is most efficient for the given temperature and size?

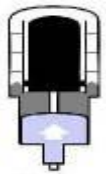
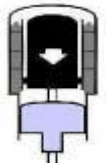
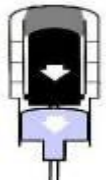
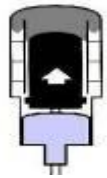
How is cooling power created? (2)

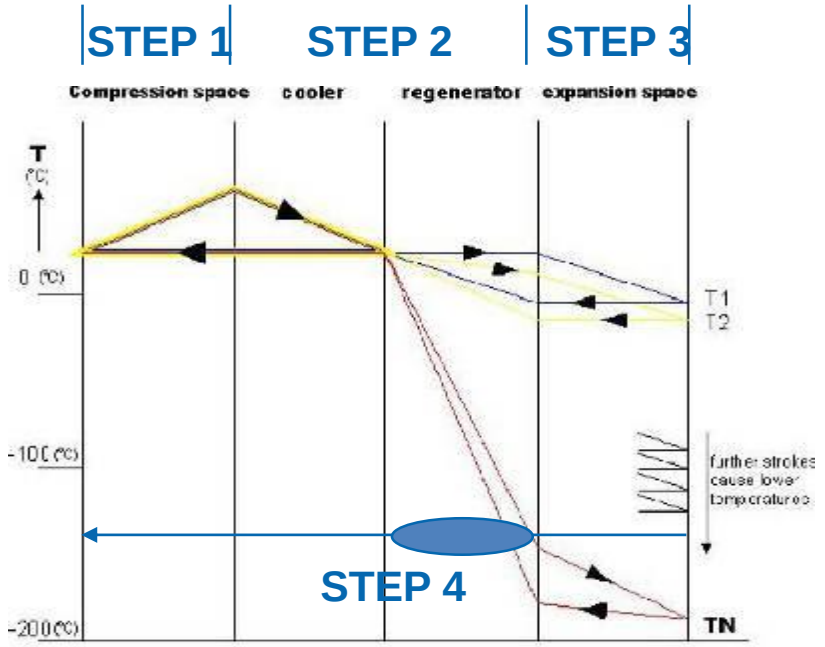
- Stirling Cryogenerator interior



How is cooling power created? (3)

- Stirling Thermodynamic Cycle

	**Step 1** Helium gas is compressed.
	**Step 2** Compression heat is removed in the cooler. (The helium gas is pre-cooled in the regenerator).
	**Step 3** By expansion, energy is extracted from the condenser head and thereby the product gas.
	**Step 4** The cold from the helium gas is stored in the regenerator during displacement of the gas to step 1

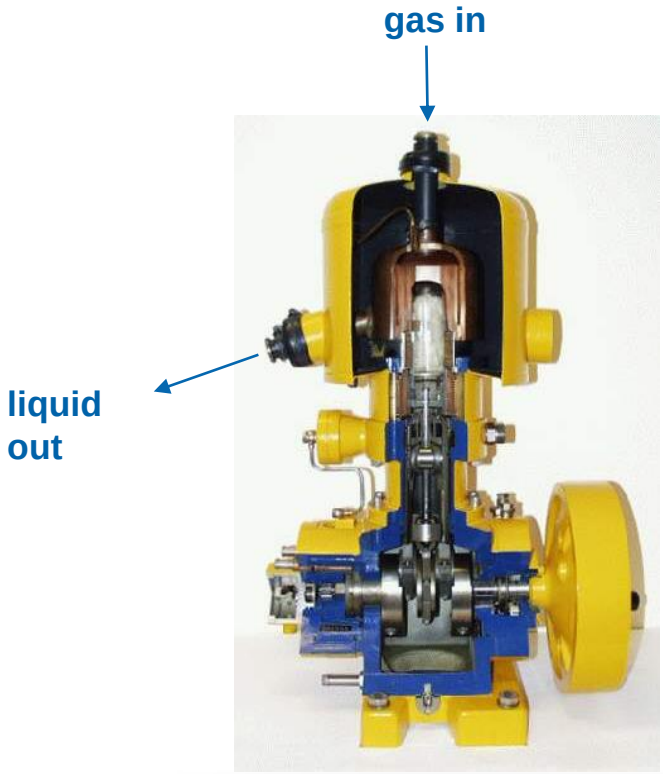


How to integrate? (1)

- Stirling Cryogenerators
  - Internal cold generation by He gas: methane is not part of process
  - Simple integration: at the LNG process side the Stirling Cryogenerator is only a heat-exchanger.
  - Small enough & efficient to fit biogas size liquefaction
  - Capacity range 0.25 to > 10 ton/day.

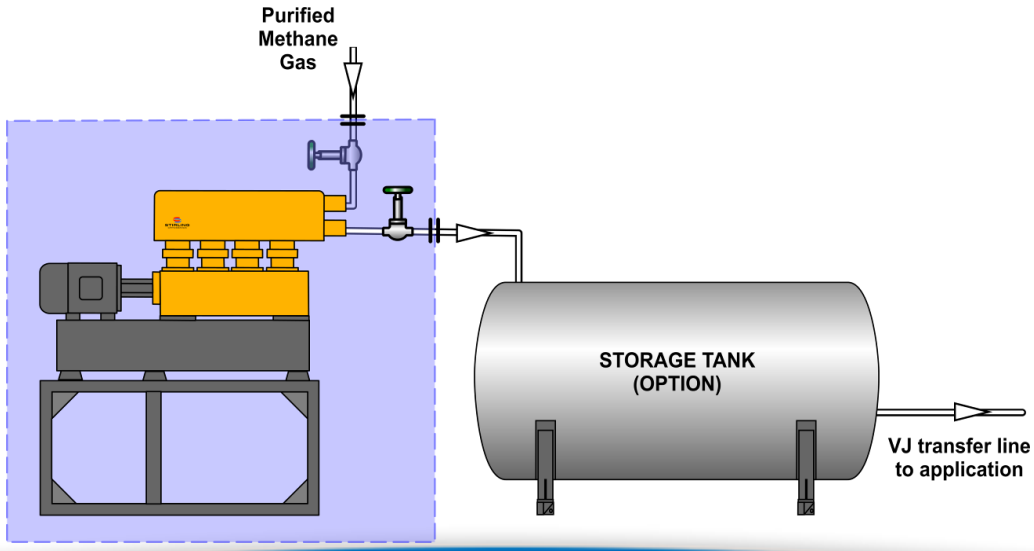
How to integrate? (2)

- Heat exchange to liquefaction process



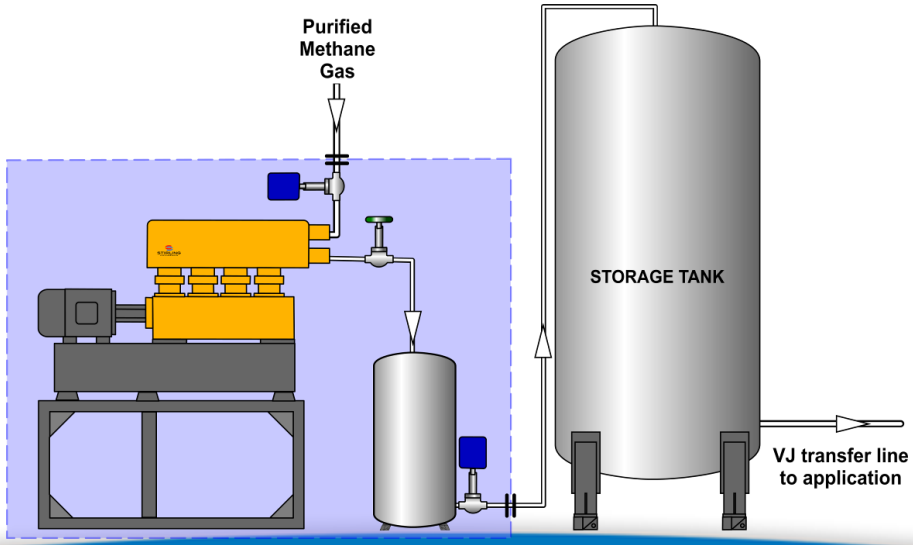
How to integrate? (3)

- Directly into main storage vessel
  - Purified gas is fed to the cryogenerator
  - Gas is liquefied and fed to main storage vessel



How to integrate? (4)

- Via transfer vessel
  - Purified gas is fed to the cryogenerator
  - Gas is liquefied into transfer vessel
  - Periodic transfer to main storage vessel



Why liquefaction of bio-methane? (1)

- To make more money
- The issue: how to best valorize your methane molecule.
- Classic alternatives:
  - Generation of electric power
  - Feeding into gas grid

Why liquefaction of bio-methane? (2)

- Not to loose money:
  - All methane that is (potentially) produced must be used.
  - As philosophy a biogas plant is an environmental friendly and green installation: you can not vent methane that you can not sell.
  - Venting is both legally nor marketing wise acceptable, even if economically the most attractive.

Why liquefaction of bio-methane? (3)

- Gas is turned into liquid as "logistic solution":
  - Without, customers must 'connect' directly to the biogas plant by gas or electric grid.

- Producing bio-LNG opens new sales channels:
  - LNG allows transport to anywhere, to markets now beyond reach.

Why liquefaction of bio-methane? (4)

Producing bio-LNG opens new markets:

- As transport fuel: interesting for trucking
  - Transport companies want LNG to convert their diesel trucks.
  - Less pollutant, less noise. For environmental care, branding, legislation by cities.
    E.g. supermarket delivery.
  - Lower cost than diesel. Or at least not more expensive.
  - Less fueling (more km's on a tank)
  - Same for ships.

Why liquefaction of bio-methane? (5)

- As heat source:
  - Interesting for stand-alone factory or village grids.
  - Now buying LNG from fossil resources.
  - Converting from LPG or diesel.

- Gas grids buying gas
  - If the biogas plant is not next to the gas grid, liquefaction is a logistic solution.
    It is transported through a 'virtual pipe line', evaporated and fed into the grid.

Why liquefaction of bio-methane? (6)

- Examples:
  - Local methane grids in remote area's now buying fossil LNG.
  - Cooperation of farmers, each with its own small LNG plant. Collective set-up with central organised collection of LNG (just like milk) to be transported to a central evaporation and injection point.
  - Truck and fuel station companies in search of LNG.

Economics (1)

- Whether producing LNG is more beneficial depends local circumstances, laws and economics.
  - What is the price per kW you get? (and what does it cost?)
  - Can you feed into the electric grid?
  - What is the price per m^3?
  - Can you feed into the gas grid?
  - What is price of diesel / LPG?
- So, *if* you can sell all your bio-methane to both electric and gas grid for a high price…

Economics (2)

- What does liquefaction cost? Example:
  - 1.5 ton/day LNG @ 3 barg
  - 2x StirLNG-4 liquefier
  - Investment € 550.000, depreciation over 5 years
  - Power consumption 100 kW @ € 0.10 / kWh
  - Consumables costs € 5.000 /y
  - Costs APEX+OPEX € 367; => € 400 per ton
    = € 0.16 per liter LNG
    = € 0.28 per Nm^3
    = € 0.40 per kg

Excluding additional gas treatment and LNG handling.

Economics (3)

- Does this pay off?
  - Assume factor 1,5 for extra treatment and handling
    => Total costs € 600 per ton
    = € 0.24 per liter LNG
    = € 0.42 per Nm^3
    = € 0.60 per kg
- Examples:
  - LNG sells for € 0.80/kg (NL, average 2014, excl. taxes), cheaper than diesel per km
  - In France injecting into the grid pays € 1.50/ Nm^3

Conclusions

- It is technically possible to produce LNG from bio-methane at any site.
- When planning to produce LNG, a market must be found to sell it.
- Whether bio-LNG production pays off depends much on local circumstances, even per area.
- Because liquid methane is easy to transport, new markets can be explored which are otherwise out of reach.

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