STIRLING CRYOGENICS

Small scale boil off gas (BOG) re-liquefaction systems

As presented by Francesco Dioguardi
at the 7th Gas Fuelled Ships Conference,
Hamburg, November 17, 2016

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STIRLING
CRYOGENICS

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

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CRYOZONE
THE CRYO CREATIVES

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STIRLING CRYOGENICS

StirLNG-4

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CONDITIONING OF LNG

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Why conditioning of LNG?

To prevent (a) LNG storage (cargo or fuel) from venting (pressure control):

- Safety, environmental & economic
- Keep LNG “cold” = value
- To maintain the composition of the LNG (mixture)
- Conditioning can be done by:
  - Re-liquefying the (excess) boil off gas

  or
  - Cooling the liquid

Both methods will decrease the tank pressure

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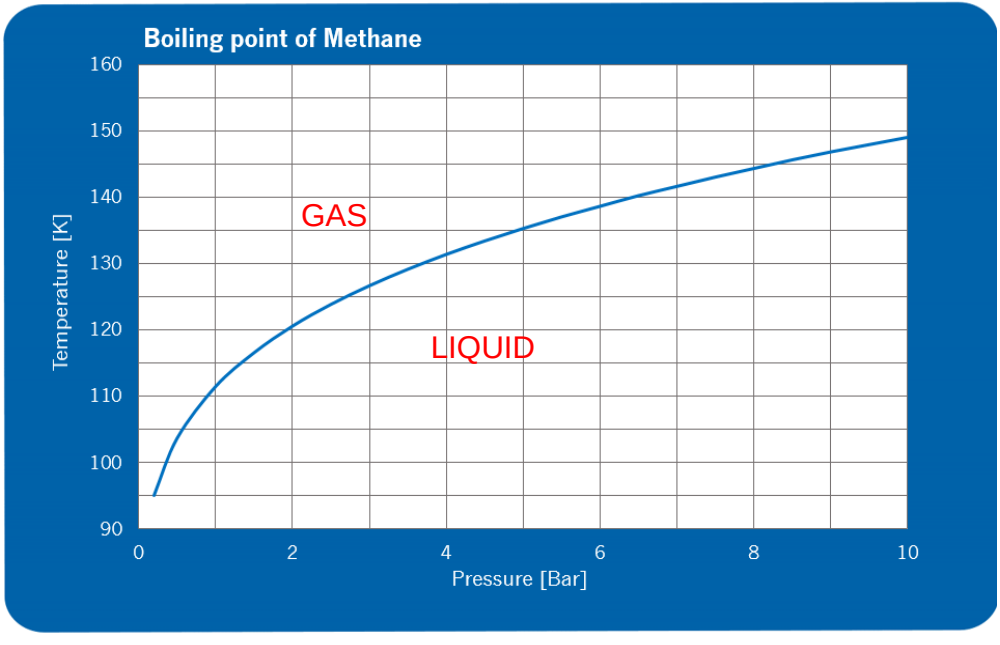
Conditioning of LNG



- Liquefaction temperature of LNG increases with increasing pressure
- Reducing the pressure of a system will cool down the liquid & reducing liquid temperature will reduce pressure (as gas and liquid want to stay in equilibrium)

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THE STIRLING CYCLE

to create cryogenic cooling power

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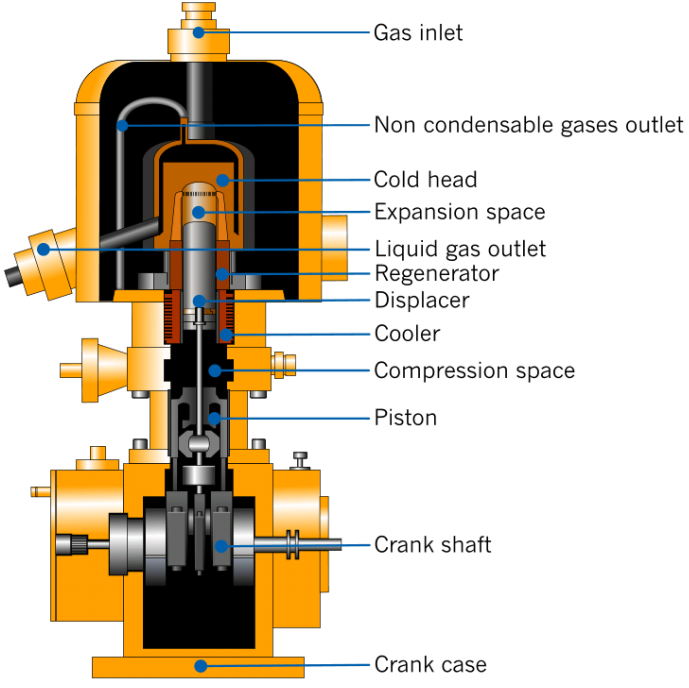
Stirling thermodynamic cycle

- Stirling Cryogenerator interior



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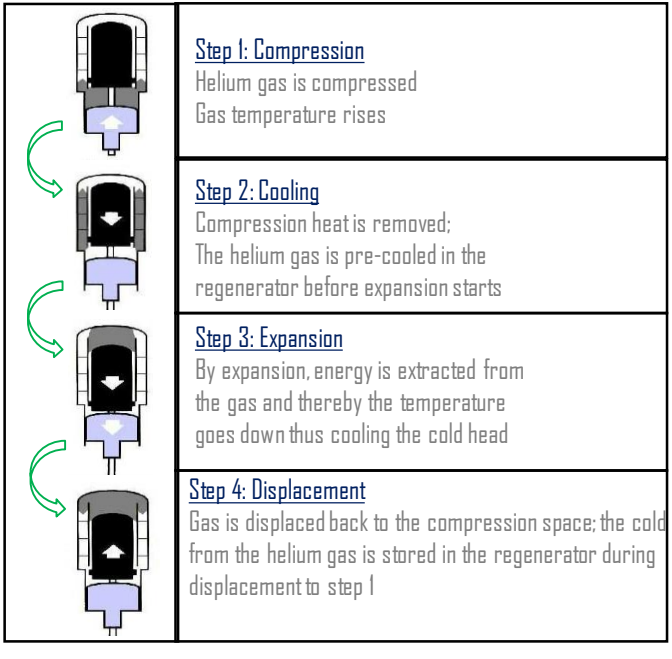
Stirling thermodynamic cycle

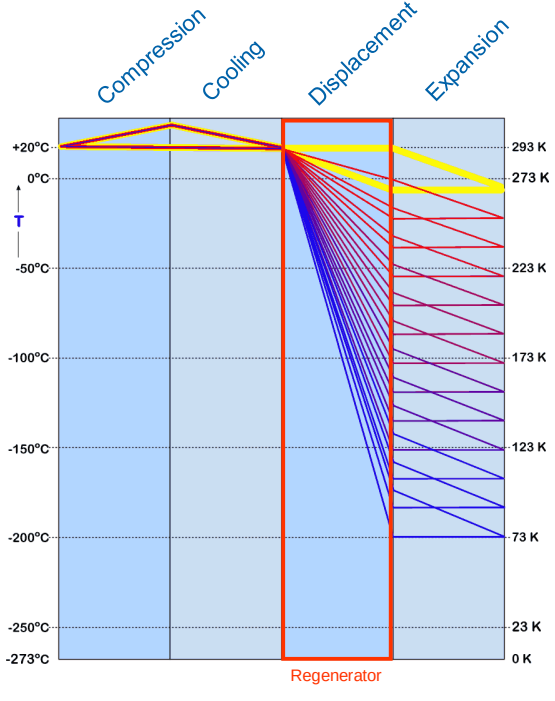


Step 1: Compression
Helium gas is compressed
Gas temperature rises

Step 2: Cooling
Compression heat is removed;
The helium gas is pre-cooled in the regenerator before expansion starts

Step 3: Expansion
By expansion, energy is extracted from the gas and thereby the temperature goes down thus cooling the cold head

Step 4: Displacement
Gas is displaced back to the compression space; the cold from the helium gas is stored in the regenerator during displacement to step 1



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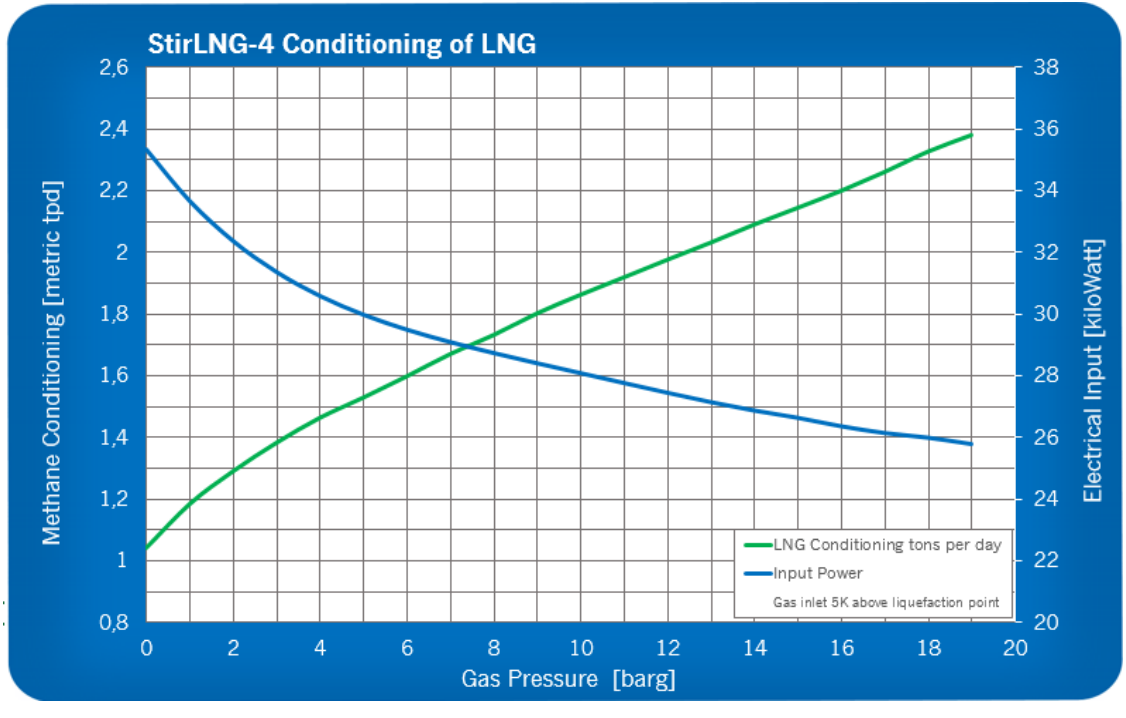
Cooling capacity

- StirLNG-4



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EASY PROCESS INTEGRATION

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Easy process integration

- 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 maritime BOG size re-liquefaction
- Capacity range 0.25 to > 10 ton/day.

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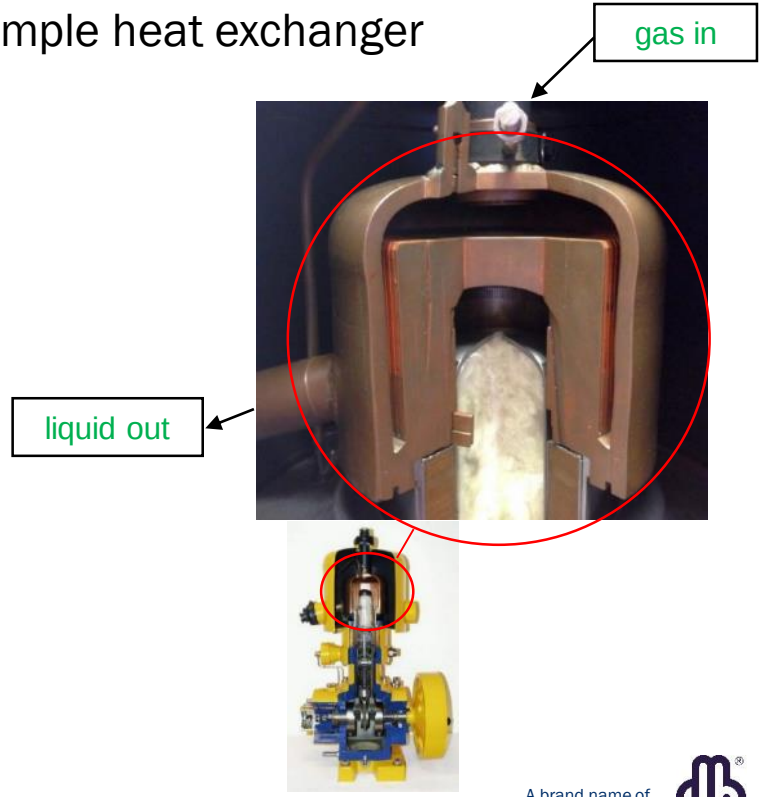
Easy process integration

- The liquefier works as a simple heat exchanger either for gas or liquid
- No compression of LNG
- No contamination of LNG
- High efficiency
- Scalable, flexible and redundant



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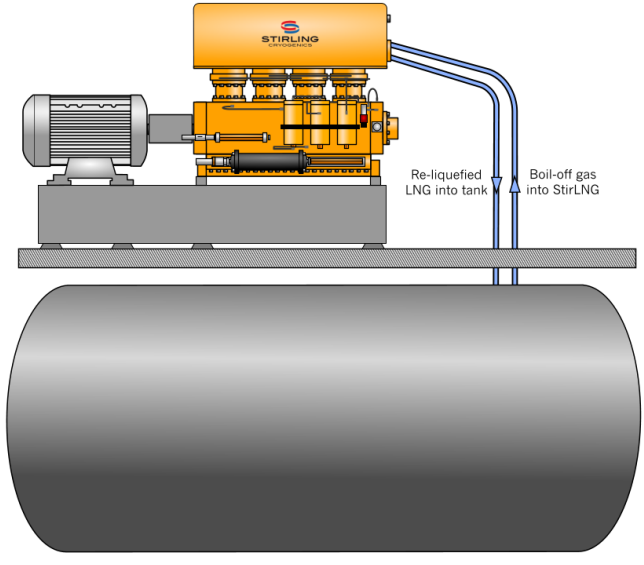
Conditioning by re-liquefaction of BOG

- Cold boil-off gas, directly from the tank, is fed to the Cryogenerator
- Gas is re-liquefied and fed back to main storage vessel
- No pumping required
- Driving force is pressure difference and gravity
- T of liquid will decrease with lower head pressure



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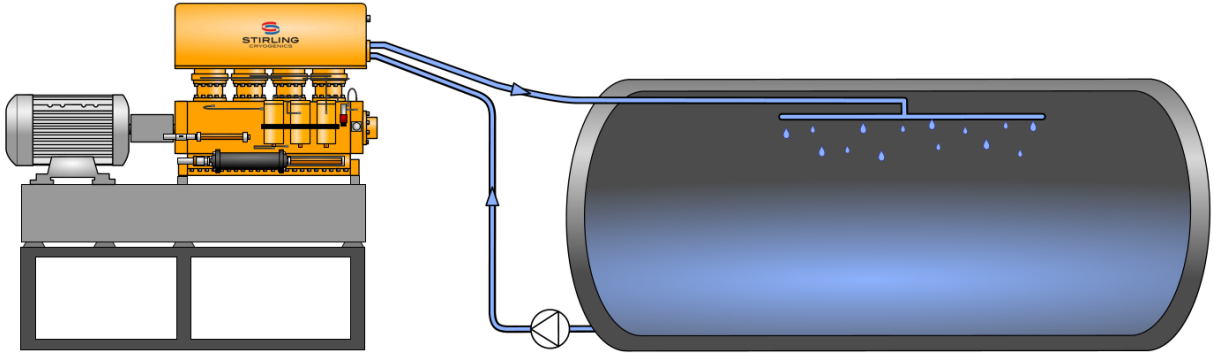
Conditioning by liquid sub-cooling

- Liquid from the tank is pumped through the HX of the liquefier, decreasing its temperature
- Colder liquid re-enters the tank reducing overall T and pressure



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ADAPTATIONS FOR MARITIME USE

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Adaptation for Maritime usage

- Modifications made for maritime application:
  - To assure functionality during roll and pitching
  - Allow static inclination during (un)loading
  - Vertical motion due to waves
  - Vibrations
  - Corrosion
  - Remote operating
  - Modifications to meet regulations (ABS, USCG, UL etc.)

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Adaptation for Maritime usage

- Corrosion prevention for maritime circumstances
- Lubrication system and LNG outlets of StirLNG-4 adapted for 22,5° dynamic roll and pitch,
  refer to videos
- Static tilting up to 15° each direction
- Free directional positioning on ship
- For USCG: separation of Cryogenerator and motor by bulk head with rotating seal
- ABS Certified, other notified bodies upon request

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ABS Type Approval

Amongst others 22,5° Roll & pitch test

- Link to roll test clip
- Link to pitch test clip

Note:

Units are in operation during these tests to proof their full functionality

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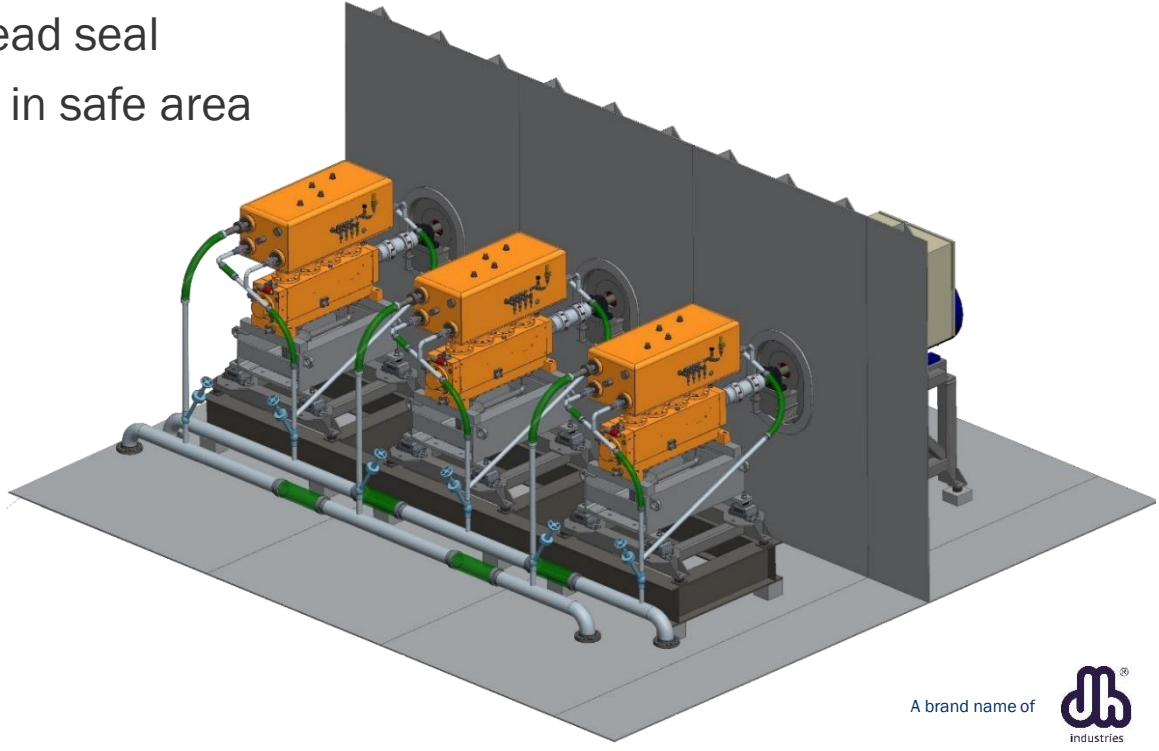
Adaptation for Maritime usage

USCG requirement:

- Bulk head seal
- Motors in safe area



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FIRST MARITIME PROJECT
DESIGN AND PRODUCTION

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2200 M³ LNG Bunker Barge

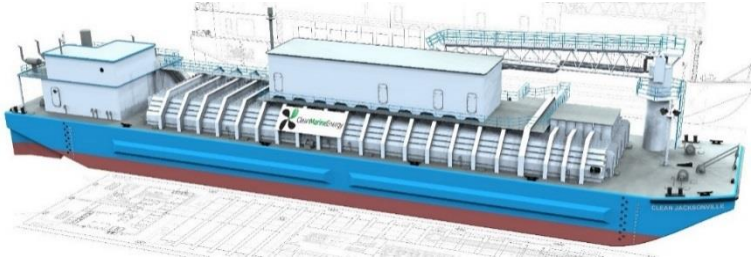
- Based on conceptual design developed by GTT
- Single cargo tank of Mark III Flex technology with BOR 0.38%/day
- Cold LNG delivery ensured by 6 Stirling StirLNG-4 cryocooler units

GTT North America

GAS Entec Solutions for Gas Engineering

CleanMarineEnergy Solutions for emissions compliance

CONRAD SHIPYARD



BRISTOL HARBOR GROUP

ABS

United States Coast Guard U.S. Department of Homeland Security

TOTE

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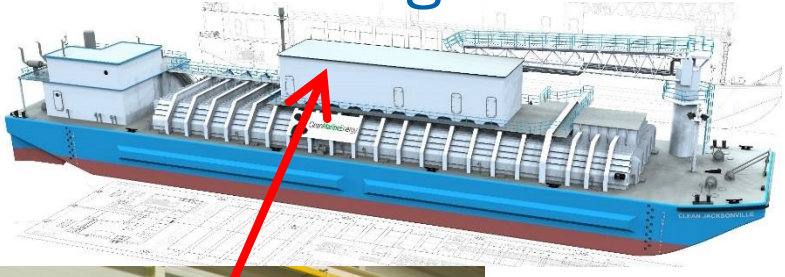
StirLNG on board LNG Barge



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StirLNG on board LNG Barge

Design Parameters 6 x StirLNG-4 units:

- Capacity:

  6 x ~ 900 kg /day = ~5,400 kg/day

  @ 0 barg and 0.5% N2

- Power consumption:

  6 x ~38 kW = ~ 228kW (+ water chillers)

- Operations:

  Each StirLNG-4 has its own controller and can start and stop on its own

- Dimensions and weight:

  lxbxh = 7,850 x 3,000 x 1,700mm (25.8’ x 10’ x 5.6’)

  ~ 8,500 kg (18,800 lbs)

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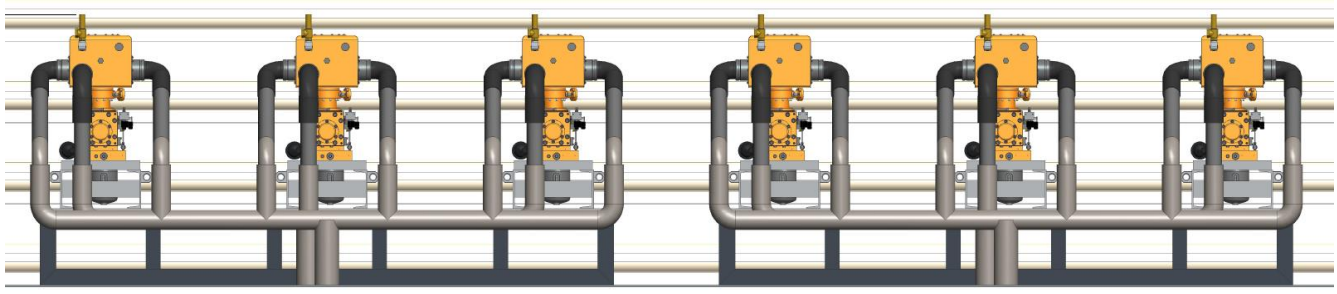
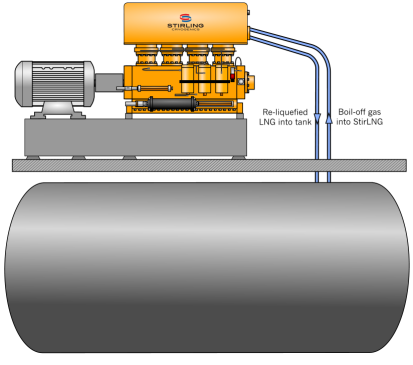
Re-liquefaction concept



Boil off gas

Liquid return



LNG

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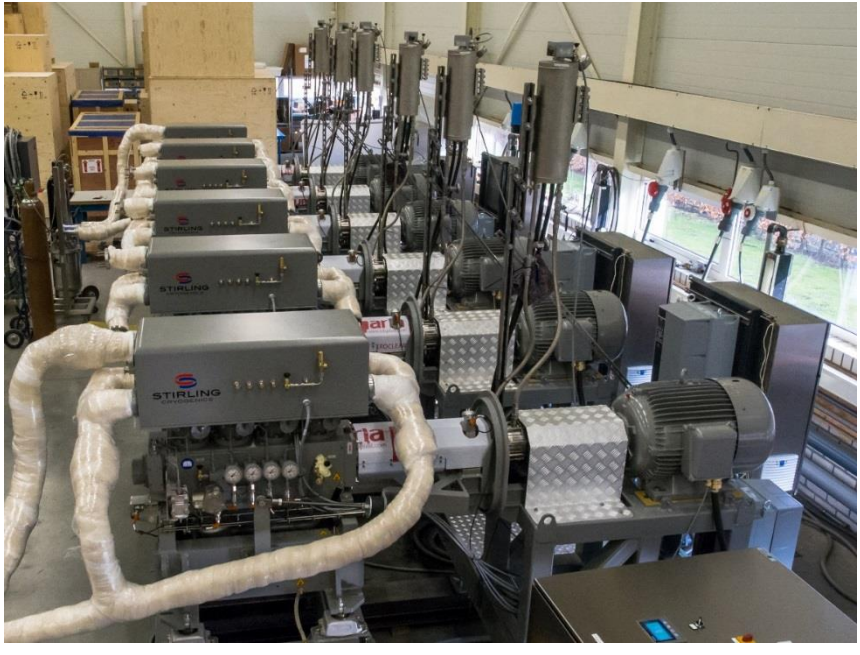
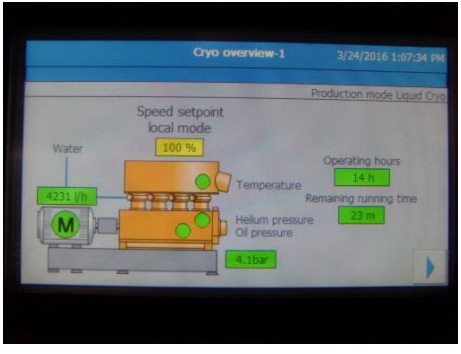
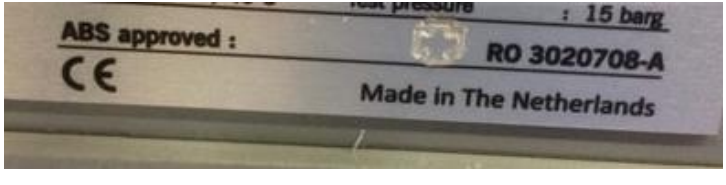
ABS TYPE APPROVED PRODUCT

Factory Acceptance Test







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Factory Acceptance Test

Each StirLNG-4 was tested for:

- Capacity:

  With LN2 at 4.8 barg (same liquefaction T as the expected BOG)
- Vibrations:

  at 5 points per unit, in 3 directions
- Temperatures:

  at 5 points per unit
- Error test:

  Each individual unit was error tested by simulating or initiating fault conditions.

  Result: All units successfully passed.

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FIRST MARITIME PROJECT
INSTALLATION

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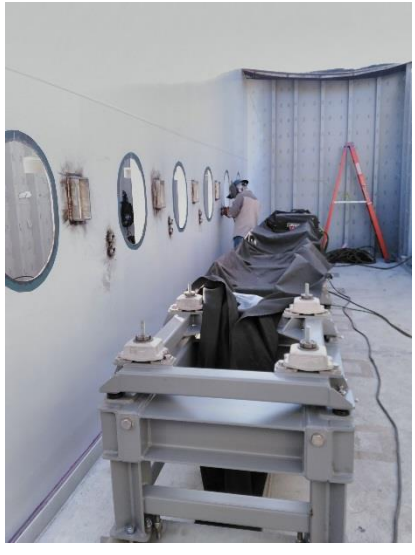
Installation at Conrad



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Installation at Conrad

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ABS TYPE APPROVED PRODUCT

Installation at Conrad

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For further information, please visit our Maritime website

http://www.stirlingcryogenics.com/en/markets/maritime

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