Cryogenic Expanders Increase Overall Efficiency of LNG Liquefaction and Regasification Plants

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3rd Annual China LNG Terminal Summit 2011

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Cryogenic expanders for Liquefied Natural Gas LNG are field proven for fifteen years. They are installed and successfully operating in most LNG liquefaction plants since 1996 until today, and are also projected for installation in future plants.

LNG expanders increase the overall efficiency of the liquefaction process, as well as the efficiency of the regasification process in receiving terminals.

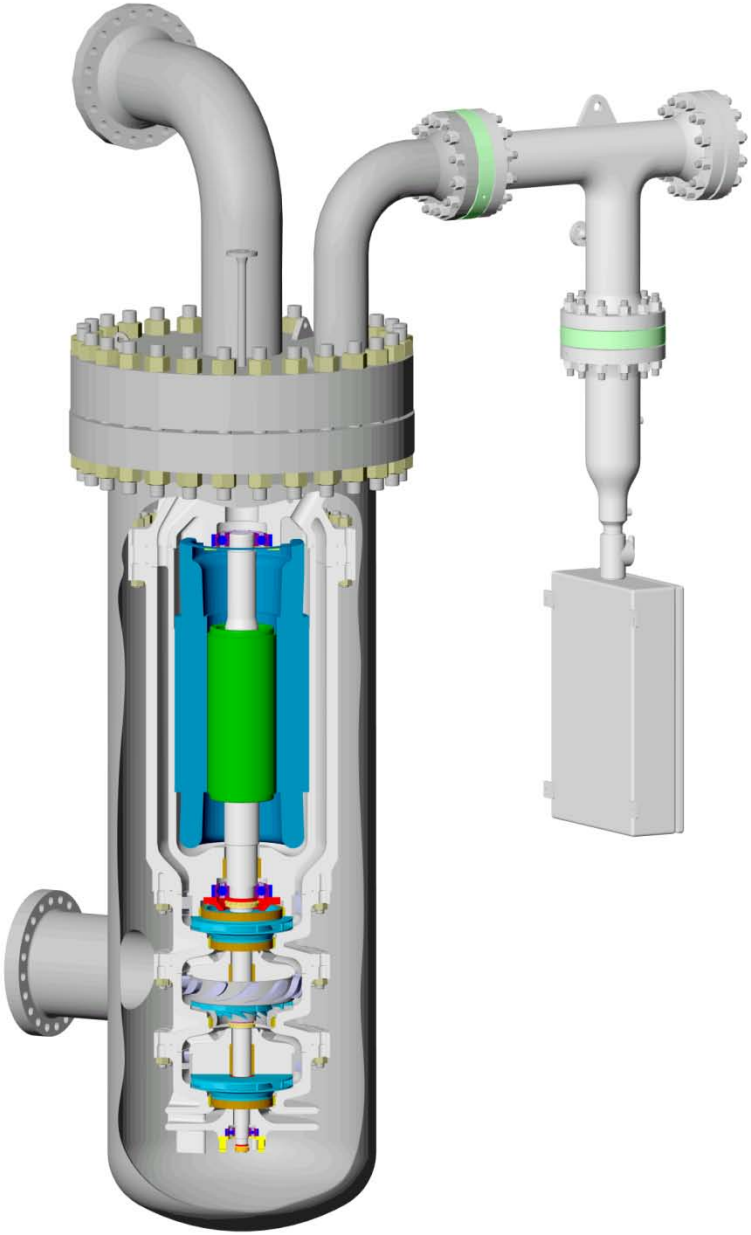
Oman LNG

LNG Expander Location

Typical design of a 3-stage LNG Expander successfully operating at Oman LNG since June 1999

3-stage
LNG Expander
successfully
operating at
Ras Laffan LNG
since 2002

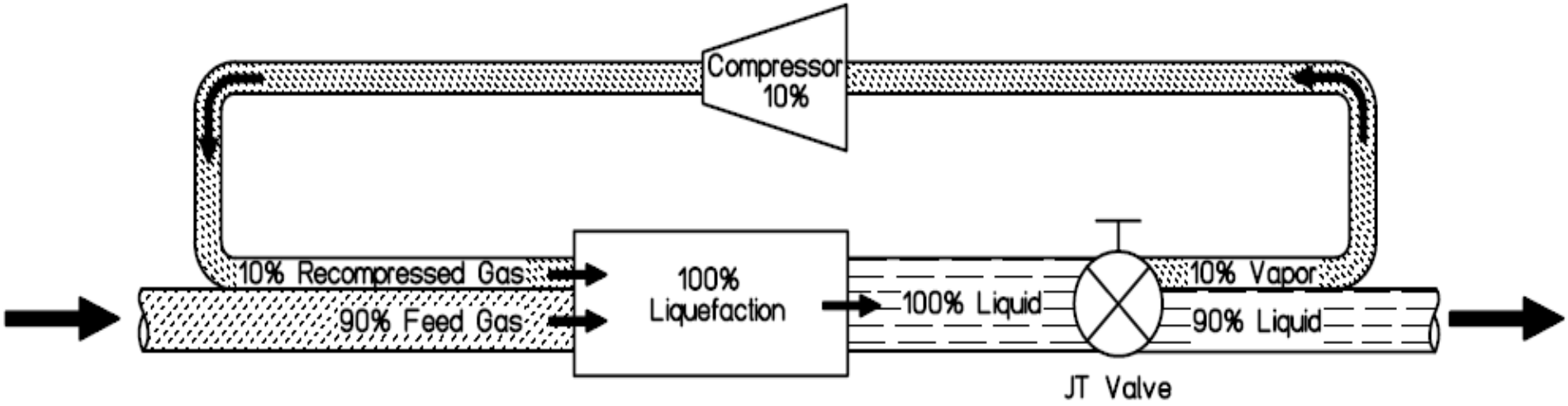
Cutaway of a typical LNG Expander with electrical generator, turbine hydraulics, aluminum housing, inside stainless steel pressure vessel with inlet, outlet and electrical junction box



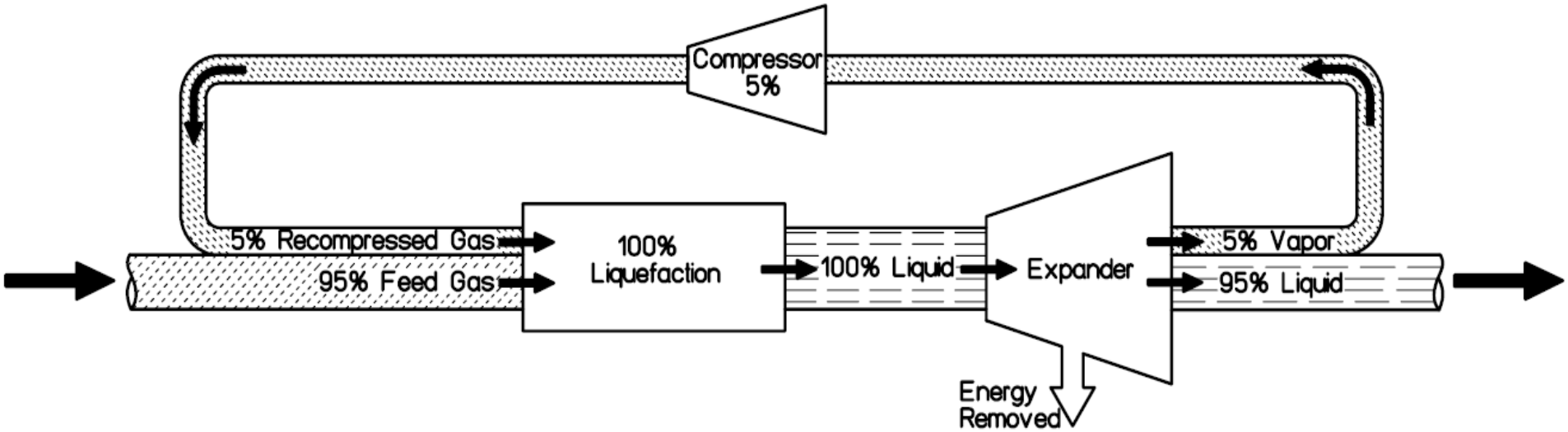
The operational objective of Cryogenic LNG Expanders within the liquefaction process is to remove energy from the condensed and pressurized liquefied natural gas

By removing energy from the pressurized LNG, the amount of liquid LNG increases by condensing more LNG vapor.

The LNG production increases by decreasing the amount of the LNG boil-off.



Liquefaction Process without and with LNG Expander for Existing Plants



Cryogenic Expanders remove energy from the LNG stream by the following principle:

Static Pressure Energy →
Kinetic Fluid Energy →
Rotating Shaft Power→
Electrical Power→

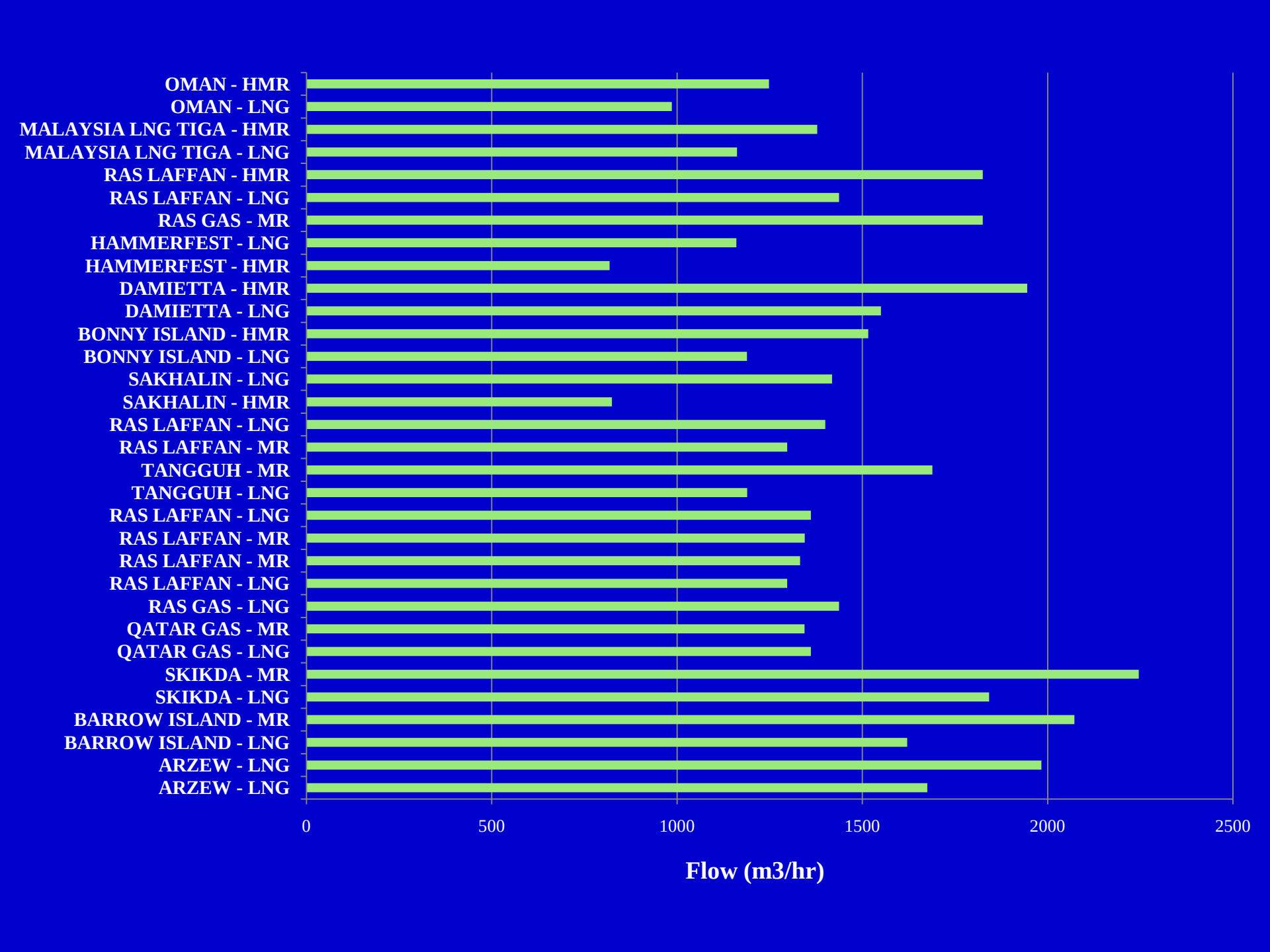
Energy in form of electrical power is removed from the LNG by connecting it to the electrical power net of the plant

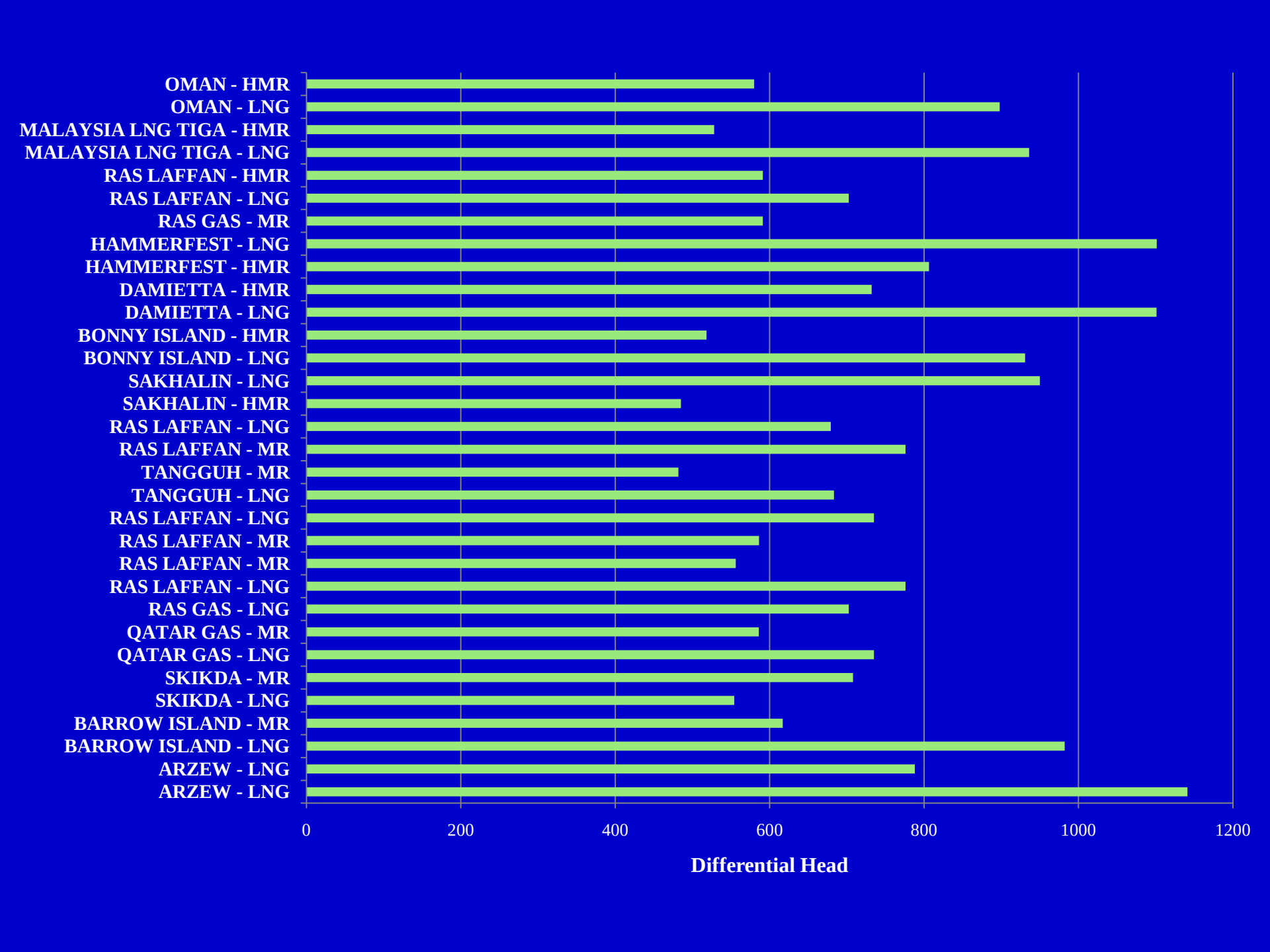
The overall efficiency of the liquefaction process is inversely proportional to the Specific Power Consumption, which is defined as the ratio of the

Total LNG Production
over the
Total Power Consumption.

The LNG Expander typically increases the LNG Production between 3 – 5 % and decreases the Total Power Consumption by the same percentage of 3-5%

By adding
3-5% to the LNG Production
and subtracting 3-5% from the
Total Power Consumption,
the Specific Power Consumption
reduces by 6-10% and
the Overall Plant Efficiency
increases by 6-10%


OMAN - HMR
OMAN - LNG
MALAYSIA LNG TIGA - HMR
MALAYSIA LNG TIGA - LNG
RAS LAFFAN - HMR
RAS LAFFAN - LNG
RAS GAS - MR
HAMMERFEST - LNG
HAMMERFEST - HMR
DAMIETTA - HMR
DAMIETTA - LNG
BONNY ISLAND - HMR
BONNY ISLAND - LNG
SAKHALIN - LNG
SAKHALIN - HMR
RAS LAFFAN - LNG
RAS LAFFAN - MR
TANGGUH - MR
TANGGUH - LNG
RAS LAFFAN - LNG
RAS LAFFAN - MR
RAS LAFFAN - MR
RAS LAFFAN - LNG
RAS GAS - LNG
QATAR GAS - MR
QATAR GAS - LNG
SKIKDA - MR
SKIKDA - LNG
BARROW ISLAND - MR
BARROW ISLAND - LNG
ARZEW - LNG
ARZEW - LNG
0
500
1000
1500
2000
2500
Flow (m3/hr)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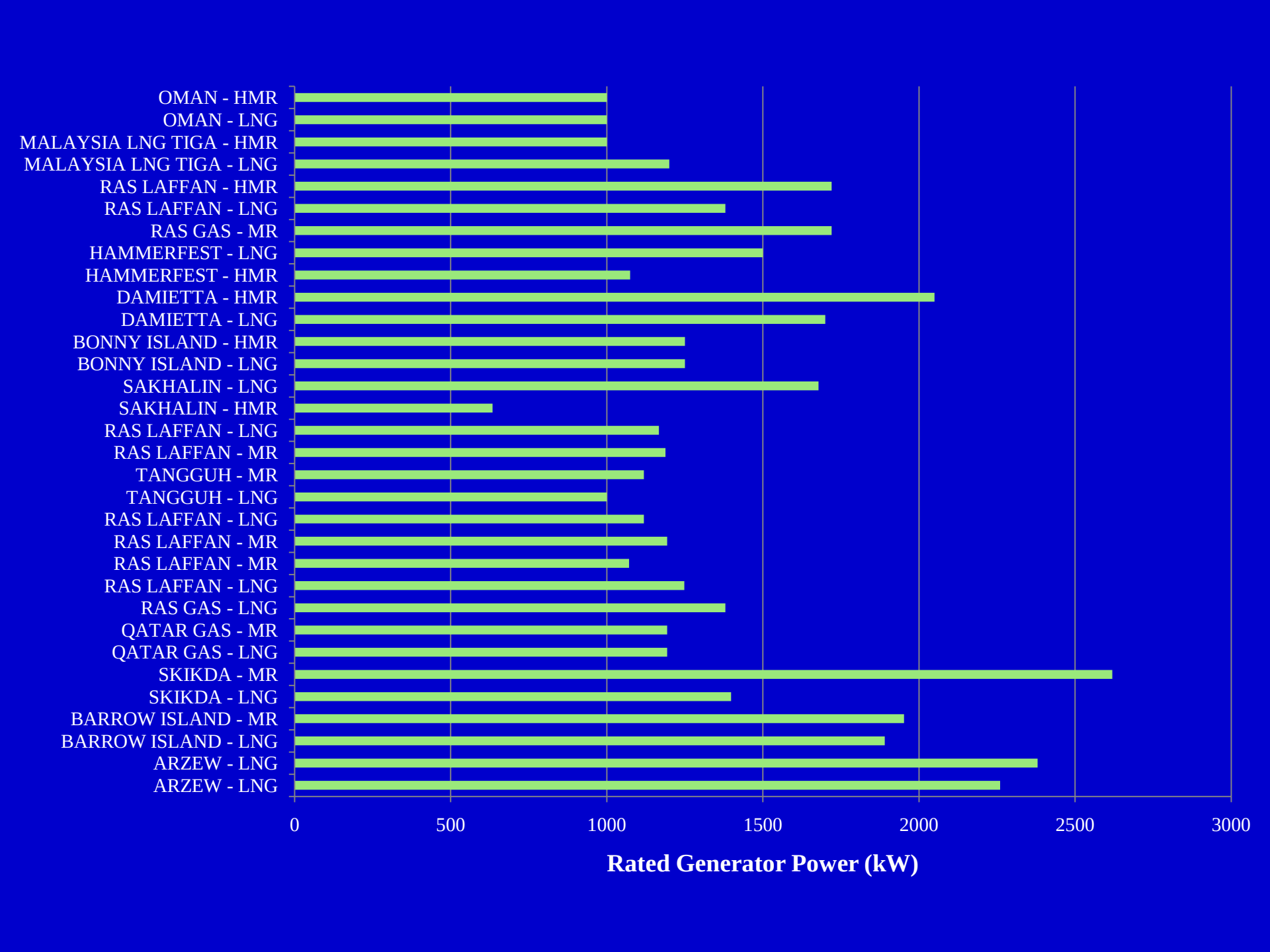
RAS LAFFAN - MR
TANGGUH - MR
TANGGUH - LNG
RAS LAFFAN - LNG
RAS LAFFAN - MR
RAS LAFFAN - MR
RAS LAFFAN - LNG
RAS GAS - LNG
QATAR GAS - MR
QATAR GAS - LNG
SKIKDA - MR
SKIKDA - LNG
BARROW ISLAND - MR
BARROW ISLAND - LNG
ARZEW - LNG
ARZEW - LNG
0
200
400
600
800
1000
1200
Differential Head

The electrical power or energy removed by the LNG Expander is proportional to the LNG Flow and to the Differential Head or Pressure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RAS LAFFAN - MR
RAS LAFFAN - MR
RAS LAFFAN - LNG
RAS GAS - LNG
QATAR GAS - MR
QATAR GAS - LNG
SKIKDA - MR
SKIKDA - LNG
BARROW ISLAND - MR
BARROW ISLAND - LNG
ARZEW - LNG
ARZEW - LNG
0
500
1000
1500
2000
2500
3000
Rated Generator Power (kW)

The increase in LNG Production
is directly proportional to
the energy removed by
the LNG Expander.

1 kW of removed electrical power
produces
60 tons/year of additional LNG

Increase in LNG production by the generated power of the LNG expander

1 kW	60 t/year
10 kW	600 t/year
100 kW	6,000 t/year
500 kW	30,000 t/year
1000 kW	60,000 t/year
1500 kW	90,000 t/year
2000 kW	120,000 t/year
2500 kW	125,000 t/year

Increase in monthly LNG revenue by the generated power of the LNG expander

1 kW	1,000 $/month
10 kW	10,000 $/month
100 kW	100,000 $/month
500 kW	500,000 $/month
1000 kW	1,000,000 $/month
1500 kW	1,500,000 $/month
2000 kW	2,000,000 $/month
2500 kW	2,500,000 $/month

The investment for an LNG Expander is typically less than 3,000 $/kW. With a monthly revenue of 1,000 $/kW the LNG Expander has a payback time of less than 3 months. Only a few investments in industry are known with such a short payback time.

LNG Receiving Terminals

Cryogenic Expanders in LNG Regasification Plants

LNG Regasification Process

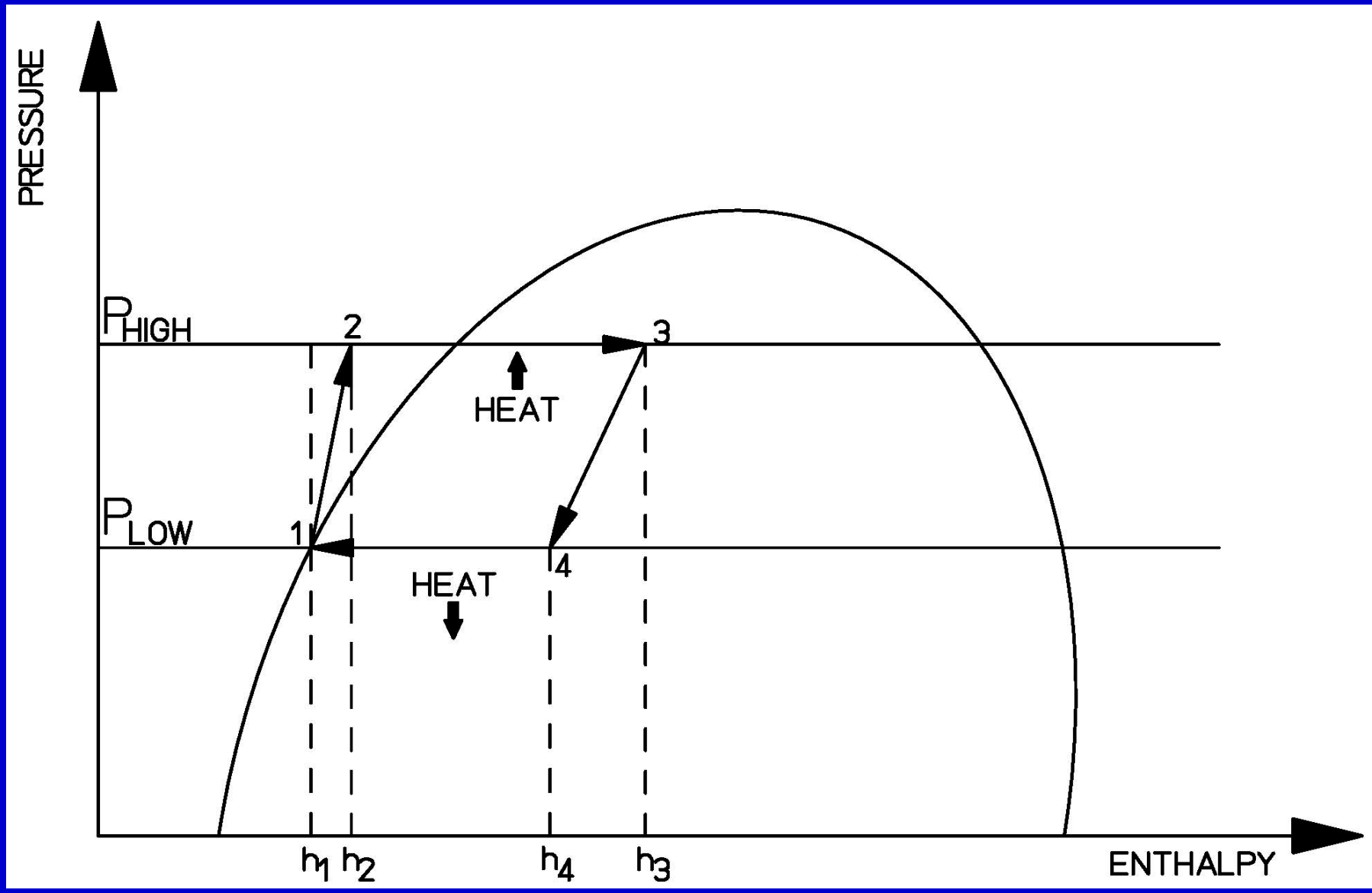
Liquid Natural Gas is stored at the receiving terminal in insulated tanks at atmospheric pressure and a temperature of 111 Kelvin.

For regasification and distribution the LNG is pumped to high pressure and then heated to vaporize into its gaseous state.

Power Recovery from LNG Regasification

LNG Regasification plants are large heat sinks and require also large heat sources.

The temperature difference of 170 C between the heat source and the heat sink provides the pre-condition for an efficient power recovery.



Thermodynamic Rankine Power Cycle

Schematic Description of Power Cycle

1→2

Pump pressurizes liquefied propane from low to high pressure

2→3

Pressurized Propane is heated by passing through the electrical generator and the heat exchanger

3→4

Pressurized and heated propane expands in a cryogenic expander from high pressure to low pressure

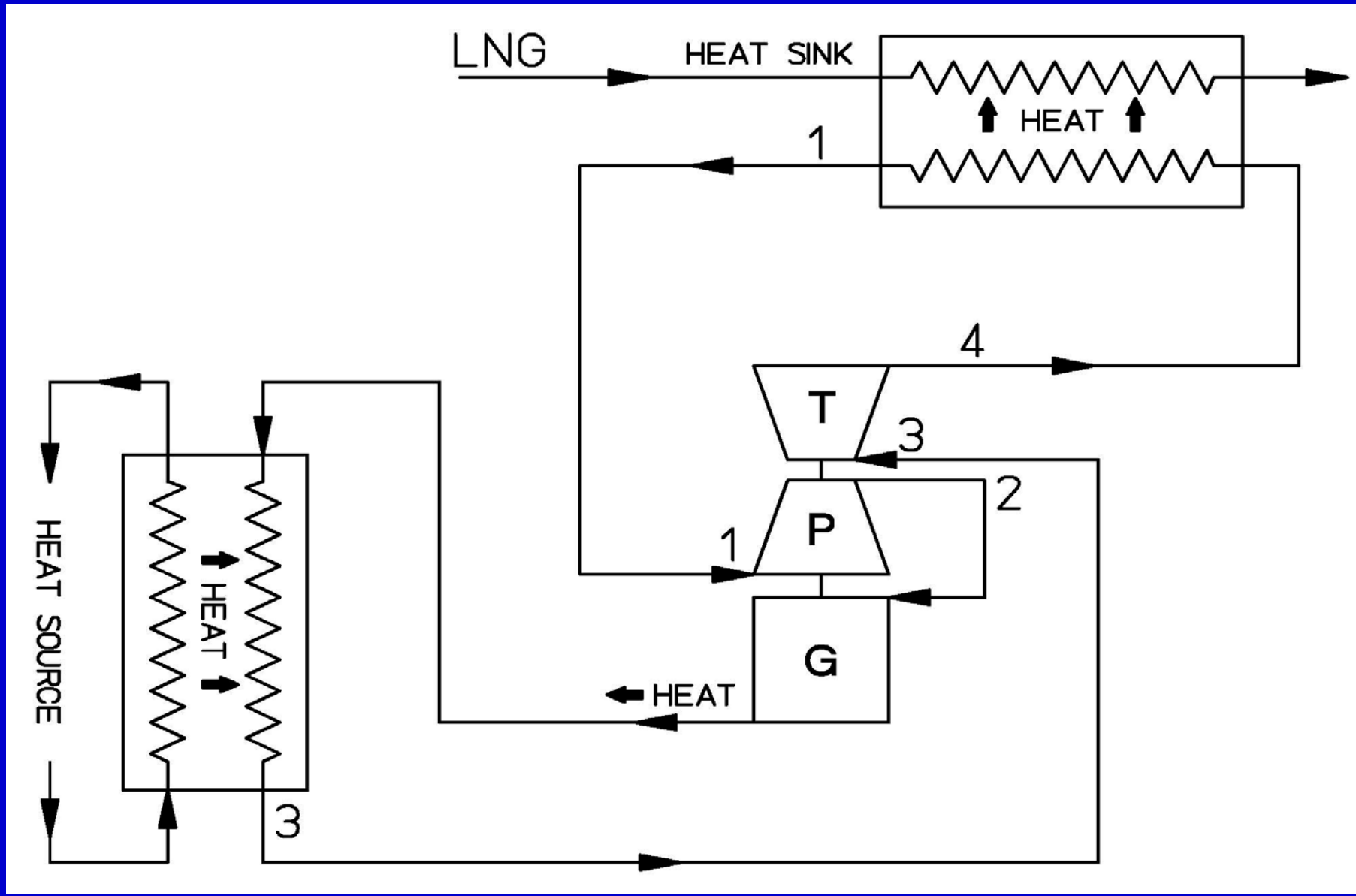
4→1

The expanded two-phase propane condenses in a heat exchanger cooled by the LNG for regasification

Power Recovery Using a Pump Two-Phase Expander Generator

For the power recovery in LNG Regasification plants the proposed cryogenic working fluid for the Rankine Power Cycle is liquefied propane gas.

To achieve a higher efficiency the liquefied propane gas is passed through two heat exchangers and one set of a Pump Two-Phase Expander Generator, a compact assembly of a pump, a two-phase expander and an induction generator integrally mounted on one rotating shaft.



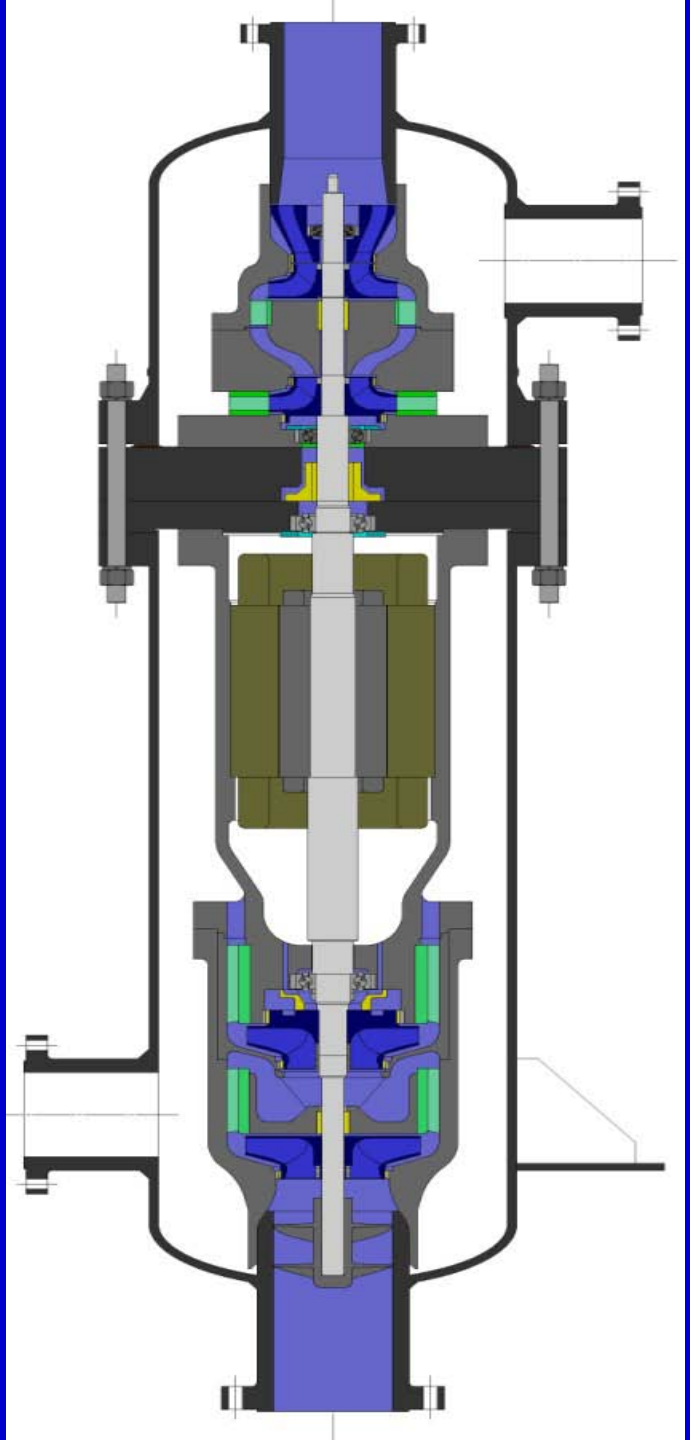
Schematic for Power Recovery

The compact assembly of a

Pump Two-Phase Expander Generator

consists of

a pump,
a two-phase expander, and
an induction generator
integrally mounted on one rotating shaft.



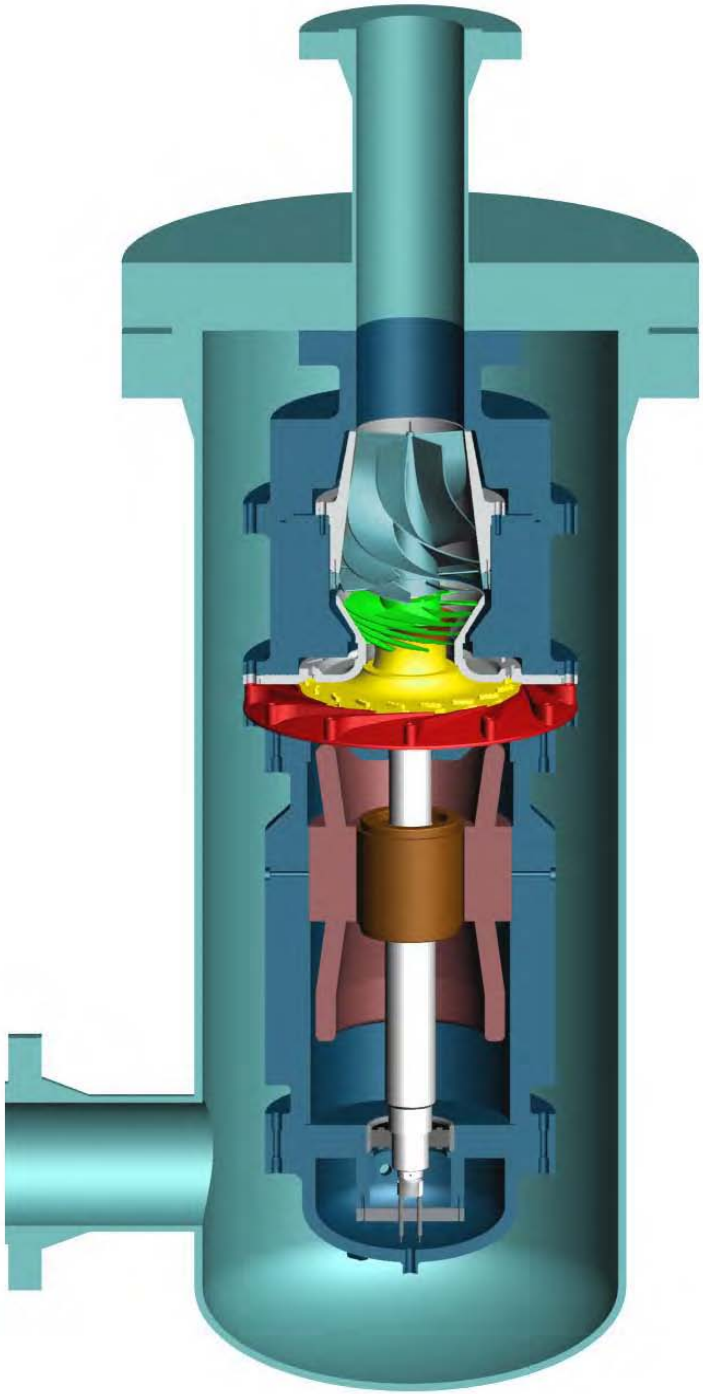
Cryogenic Pump Two-Phase Expander Generator

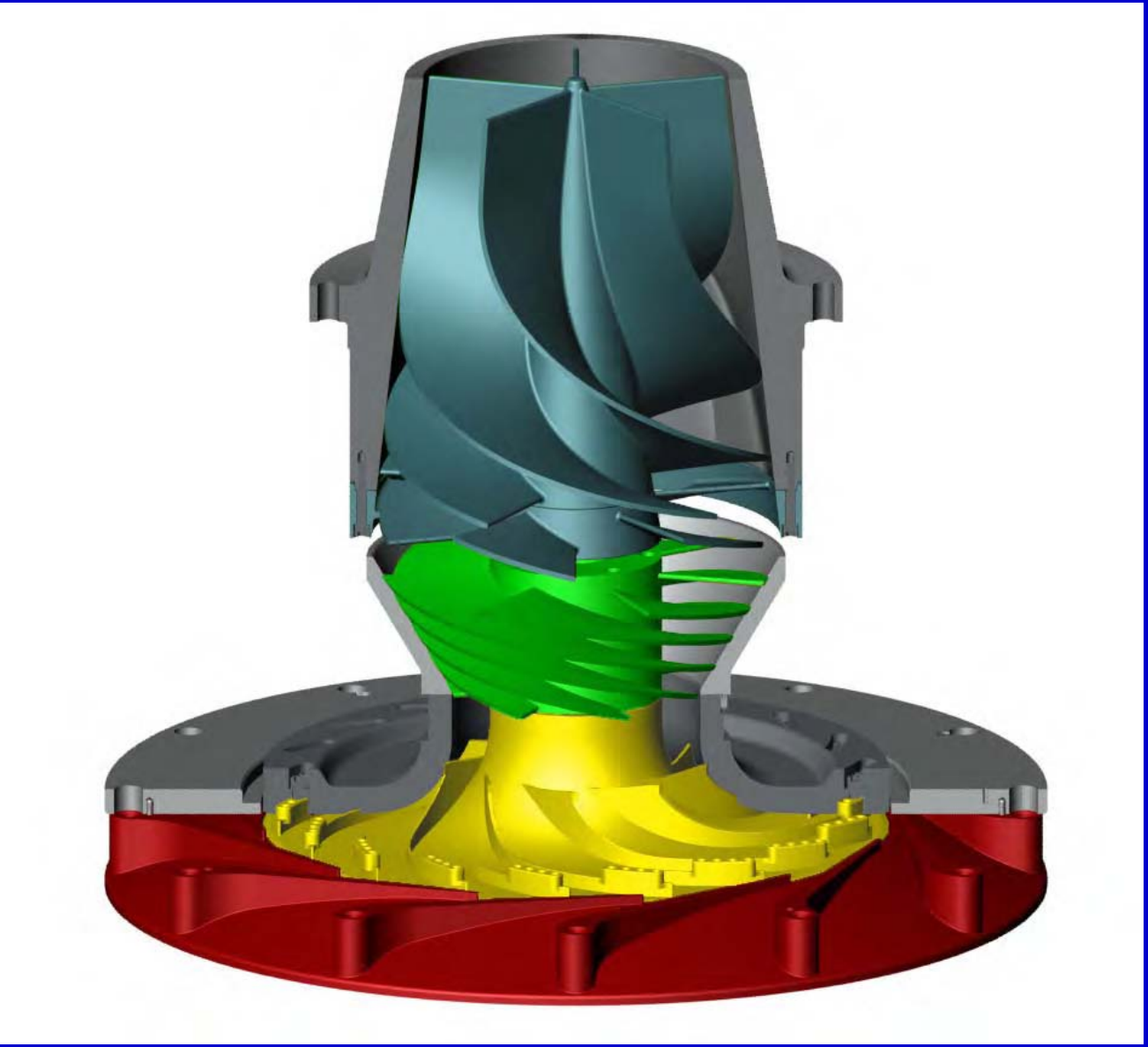
The pressurized fluid passes directly from the pump through the generator housing cooling the generator, then exit to the side and passing through the heat exchanger.

The leakage through the seal and the thrust is minimized due to equal pressure on both sides of the seal and opposing directions of the thrust forces.

Existing Field Proven Two-Phase Expanders

Cross section of a Two-Phase Liquefied Gas Expander inside pressurized containment vessel with lower inlet and upper outlet nozzle





Hydraulic Assembly for Two-Phase Expansion

Cryogenic Two-Phase Expanders are successfully operating in Europe since 2003

LNG Regasification Plants are in general without any power recovery because cryogenic two-phase expanders were only recently developed.

The presented system using field proven equipment provides efficient and economical power recovery and increases the overall efficiency of the LNG Regasification process.

Thank You for your attention

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