Operational data and model extension

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Current round trip efficiency (RTE)

Output

129 kW cooling to warehouse (equiv. 51 kW electrical)

45 kW electrical power (turbines)

Input

0.42 kg/s LIN (2.13 MW)

6 kW fan power

RTE 4.5%

Includes

Electricity generated, cooling to warehouse, warehouse fan power.

Doesn’t include

Defrosts, start-up and shutdown losses, Interstage cooling from turbines (-30 to -40°C).

Assumes

COP of ammonia refrigeration (-30°C) =2.5

Energy cost of LIN = 1.4 kWh/kg (Claude cycle LN system limited to 200 Bara pressure, LIN Pressure 17 Bara)

Original concept

Original concept was to recover cold energy between turbines (turbine reheat) using a heat transfer fluid to a chilled warehouse.

Ammonia condensers (warehouse refrigeration) were used due to cost of HXs.

Assuming all cold recovered from before turbines to chilled warehouses (30 kW of chilled cooling).

RTE = 4.9%

Assumes

COP of 4 at -10°C

Design specification

Pressure (bara)	Design	Actual
After pump	15.4	16.3
Before Turbine 1	14.8	15.4
Before Turbine 2	6.4	6.7
Before Turbine 3	2.5	2.7

Turbine efficiency (%)	Design	Actual
Turbine 1	79	53
Turbine 2	81	61
Turbine 3	74	64

RTE = 5.5 %

Pump to higher pressure

Pump pressure (bara)	RTE (%)
15	5.5
30	6.0
60	6.3
75	5.7

Assumes

25% pump efficiency

If we had a liquefaction system and recycled the cold (15 bar)

RTE = 14 %

Assumes

Cold energy storage efficiency = 91 %

15 bar pressure

No waste/recovered heat

Recycled and waste heat (30 bar)

	RTE (%)
Heat recycle from liquefier @ 230°C	31
+ waste heat @ 350°C	38
+ waste heat @ 550°C	49
+ waste heat @ 650°C	55
+ waste heat @ 750°C	61

Assumes

30 bara LA storage and let-down pressures (no LA pump)

Conclusions

Demonstrator system

RTE low - Energy cost of liquefaction much higher than energy production from turbines and value of cooling to cold store warehouse

Ideal system

Reduce liquefaction cost

- Connected to liquefaction system via thermal store

Use cold at lower temperatures

- Cryogenic freezers

Increase power generation

- Recycle heat from liquefaction system via thermal store
- Further high temperature process waste heat
- Higher pressures and more efficient turbines and pumps

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