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# Heat recovery from export gas compression: Analyzing power cycles with detailed heat exchanger models

Daniel Rohde*, Harald Taxt Walnum, Trond Andresen, Petter Neksâ

*SINTEF Energy Research, Postboks 4761 Sluppen, 7465 Trondheim, Norway*

## HIGHLIGHTS

- Offshore power production from surplus heat was analyzed with focus on system size.
- Detailed heat exchanger models were used for power cycle simulations.
- Investigated cycles: subcritical, transcritical, transcritical with fluid mixture.

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## ABSTRACT

Offshore oil and gas production platforms release substantial amounts of heat to the sea. A major source of waste heat is the cooling unit for the compressed export gas. In this paper, the potential for power production from this heat source is analyzed. The emphasis was not only put on net power output, but also on system size, which is a key parameter for offshore operation. To find a suitable trade-off between those two values, a cycle calculation tool was programmed which uses detailed heat exchanger models to ensure a fair comparison of the different working fluids. A subcritical propane cycle, a transcritical $CO_2$ cycle and a transcritical cycle with a mixture of propane and ethane were analyzed. It was shown that more than 10% of the export gas compression work could be recovered. The hydrocarbon mixture shows very promising results, but a more comprehensive study is required to reach an economical decision between power output and system size.



## 1. Introduction

The Oil and Gas industry has extensive energy needs related to production and export of fossil fuels. The primary focus has traditionally been on production and safety, whereas energy efficiency is a more recent priority. The implementation of more environmentally friendly technologies is an important factor in order to reduce greenhouse gas emissions.

The energy demand on a platform is mainly covered by gas turbines which either produce electricity or directly drive gas processing compressors. One example is the export compressor train, which can be seen in Fig. 1. After the gas is extracted and separated from the produced liquids, it undergoes a series of steps (compression, intercooling, further dehydration, compression and aftercooling) before it is ducted into the export pipeline. The intercooling ensures that the dehydration takes place at optimum conditions and reduces the power demand of the second compression; the aftercooling prevents unacceptably high gas temperatures at the pipeline inlet (>100 °C). Today, the gas is usually cooled with large shell-and-tube heat exchangers or diffusion-bonded printed circuit heat exchangers (PCHE) with an indirect cooling loop. The heat is released to the sea and therefore wasted. The objective of this paper is to evaluate the utilization of the aftercooling waste heat for power production in a Rankine power cycle in order to increase the platform's overall energy efficiency and reduce $CO_2$ emissions. The utilization of the intercooling waste heat is more challenging due to the stricter temperature restriction, but a combined system might be a promising option.

A Rankine cycle's main components are pump, heat recovery heat exchanger (HRHE), expander and condenser. For sensible low temperature heat sources, heat exchanger size is the critical parameter which dominates system foot print and cost [1]. This is due to two issues: First, the heat source temperature decreases in the HRHE as heat is transferred to the working fluid and second, the system's efficiency decreases with decreasing heat source temperature. This leads to a non-linear relation between power

* Corresponding author. Tel.: +47 735 93 914.
*E-mail address:* daniel.rohde@sintef.no (D. Rohde).

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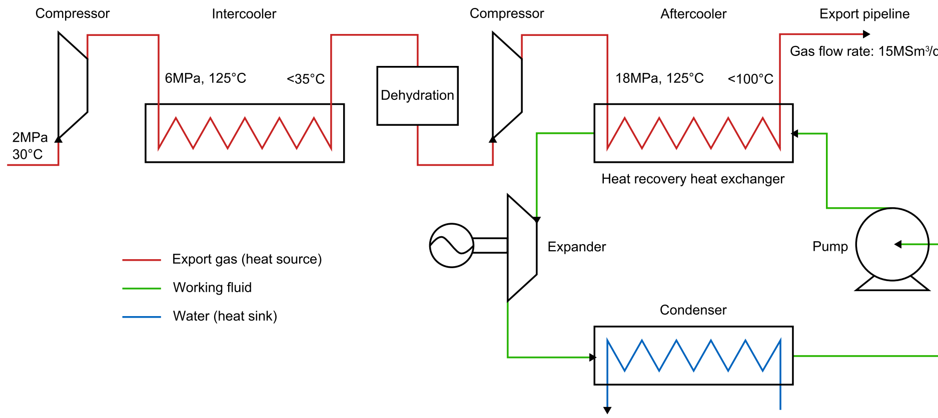


**Fig. 1.** Heat recovery system layout.

production and heat exchanger size (cost) which means that an optimum system can not be found by maximizing efficiency or net power output. Instead, a suitable trade-off between net power output and total system size has to be found. This is especially important for offshore platforms, where the available space and weight for new installations is very limited. The choice of a suitable working fluid is also an important element in such a consideration.

## 2. Methodology

A Microsoft Excel-based power cycle calculation tool was programmed using Visual Basic. Fluid properties are obtained from REFPROP 8 [2] and detailed in-house heat exchanger models were implemented for HRHE and condenser. The following sections give a detailed description of the tool and its functions.

### 2.1. Component calculation

As stated in Ref. [3], cycle calculations are often performed with simplifying assumptions for the heat exchangers like constant heat transfer coefficients, fixed pinch points or neglected pressure drops. As the heat exchangers are key components, this may give misleading results. In this study, detailed in-house heat exchanger models were used.

**Table 1**
Heat transfer and pressure drop correlations.

| | | |
|---|---|---|
| Heat transfer | Single phase plate channel | [7] |
| | Condensing in plate channel | [8] |
| | Single phase circular tubes | [9] |
| | Evaporation in circular tubes | [10] |
| Pressure drop | Single phase plate channel | [7] |
| | Two phase plate channel | [8] |
| | Single phase circular tubes | [11] |
| | Two phase circular tubes | [12] |

The models are based on an internal code that calculates important values such as hydraulic diameter, perimeter and cross-sectional area for each fluid pass, given by a detailed geometry input. Based on the geometry specification and the fluid inlet conditions, the outlet conditions are found through integration of the fluid passes and iteration on the wall temperature profile. Relevant heat transfer and pressure drop correlations from literature are utilized (Table 1). The fluid properties are calculated with the SRK EOS [4] for hydrocarbons (single component and mixtures), the Span/Wagner EOS [5] for $CO_2$ and the IAPWS IF97 formulation [6] for water. Both longitudinal and transversal wall heat conduction are accounted for. All heat exchanger models are compiled to Dynamic-Link Libraries (DLLs) and are called from Excel.

The HRHE model is based on stacked layers of multi-port tubes, and is meant to represent a generic compact heat exchanger. The wall material has been modeled as titanium. The flow is counter-current and the cross-sectional flow areas can be different for hot and cold flows. Two possible configurations are shown in Fig. 2.

The minimum flow channel diameter was set to 1 mm [13]. Fouling might occur on the natural gas side, but this has not been taken into account in this study.

A typical temperature profile result is shown in Fig. 3. The outer lines are the fluid temperatures (heat source and working fluid); the inner lines are the wall temperatures at fluid contact.

A plate and frame configuration is chosen for the condenser, as this would reduce the size and weight compared to shell and tube condensers. To increase the efficiency of the system, it is modeled with direct sea water cooled condensers, and therefore titanium is chosen as material.

A recuperator has not been included in this study, because it has been reported to be uneconomical at such low heat source temperatures [14,15]. As the focus of this work was put on the heat exchangers, pump and expander were calculated with constant isentropic efficiencies and connecting elements were neglected (see Table 2).

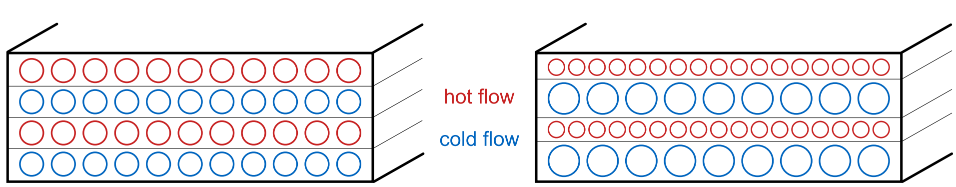


**Fig. 2.** Generic compact heat exchanger layouts.