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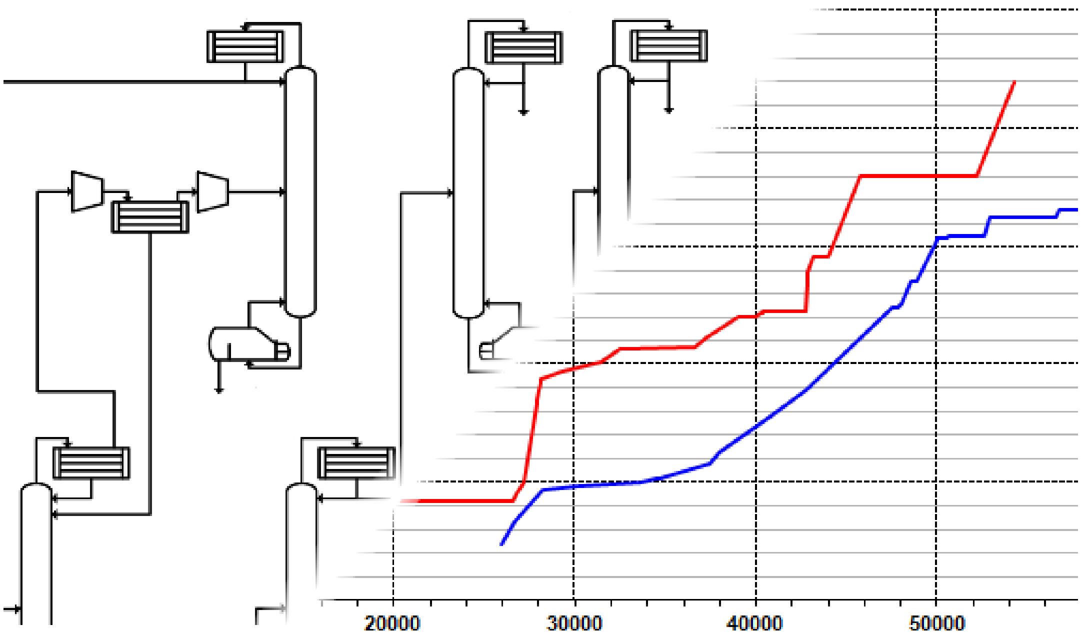

Energy recovery prospects of a distillation sequence revamp in an Amines plant

Master's Thesis within the Sustainable Energy Systems programme

EXTENDED ABSTRACT

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Göteborg, Sweden 2012

MASTER’S THESIS

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Preface

In this master's thesis study, the energy recovery prospects and the economic prospects of a proposed revamp of an Amines plant have been evaluated. The proposed revamp is analyzed using pinch technology. The study has been performed as a part of a larger Ph.D. project investigating the energy efficiency of a large industrial cluster.

The project has been carried out at the Department of Energy and Environment in the Division of Heat and Power Technology at Chalmers University of Technology, Göteborg, Sweden. It has been performed in cooperation with the company operating the investigated Amines plant at one of the sites in the industrial cluster.

According to a secrecy agreement, with the Chalmers diarienumber EM 2011/244, the full version of this master's thesis report cannot be published. Thus, this published version is limited to an extended abstract of the full report focusing on the energy recovery prospects evaluation of the study.

Göteborg, April 2012

Jonas Årsjö

Extended abstract

This master's thesis study covers an evaluation of the energy recovery prospects and the economical prospects of a revamp proposal for rebuilding parts of the distillation sequence in an Amines plant. The principal aims of the distillation sequence revamp are to increase the product yield and to reduce the hot utility used in the plant.

The Amines plant consists of two sub processes, one producing ethanol amines and one producing ethylene amines. Together, these processes produce ten different Amines products. These products are functional chemicals used in many different areas and for many different purposes. A few examples of these areas are: in the oil industry, for production of detergents and for production of pharmaceuticals

Figure 1 shows an overview of the Amines plant site. It illustrates how the Amines plant interacts with other plants and with storage areas, waste treatment facilities and utility supply centers on the site. The investigations in this study are however limited to the specific Amines plant process, as indicated by the dashed line in the figure.

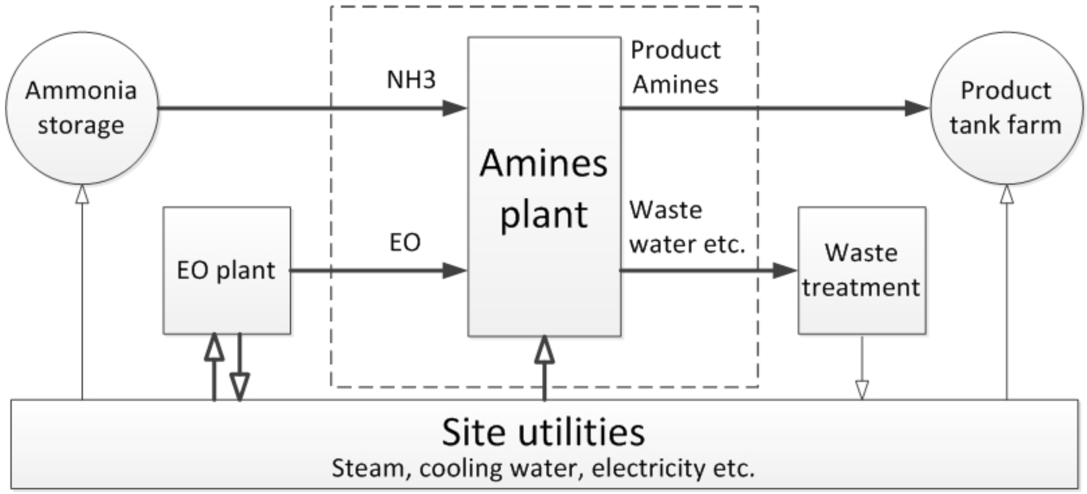
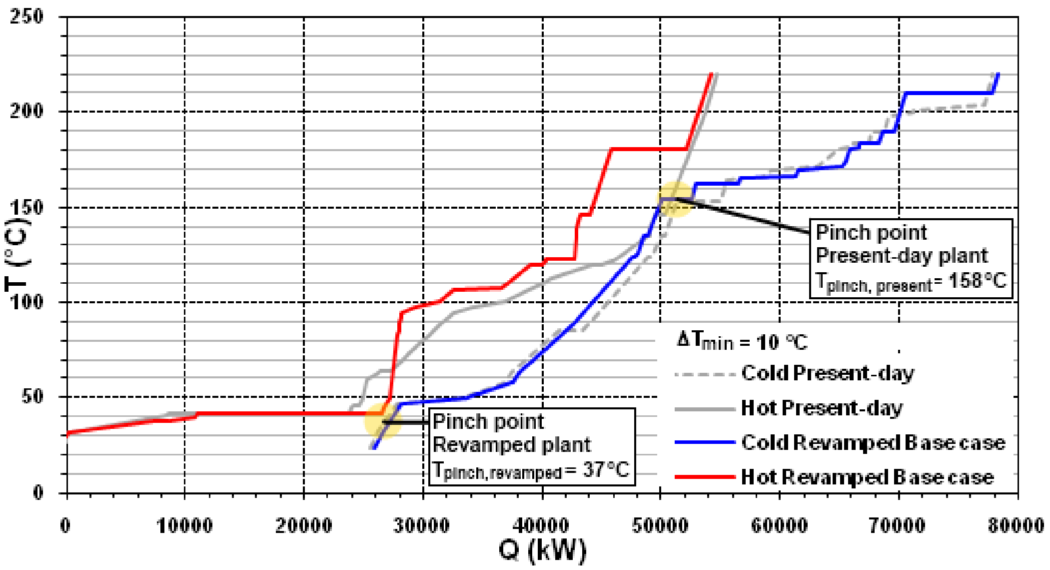


Figure 1 *The Amines plant's interaction with other site facilities, filled arrows indicate material streams and unfilled arrows indicate utility streams*

The revamp proposal targets a specific part of the distillation sequence in the Amines plant. The distillation towers included in this part of the sequence are the only equipments in the plant which are affected by the initial revamp proposal. The rest of the Amines plant is unaffected by the revamp.

The process data required in this study is based on mass and heat balances for a standard design case of the Present-day Amines plant. This standard design case is normally used in the initial stage of new design projects concerning the Amines plant. As the proposed revamp only affects a specific part of the Amines plant the process data for the standard design case data can also be used for large parts of the process in the Revamped Amines plant. To obtain data for the part of the process affected by the revamp a process simulation is performed in Aspen Plus.

Pinch technology is used to evaluate how the proposed revamp influences the process and to identify measures which can improve the energy recovery prospects of the revamp. A Base case revamped Amines plant is defined, for which a pinch study is performed based on the collected process data. A pinch study is also performed for the Present-day Amines plant. Figure 2 shows the composite curves of these different versions of the Amines plant. The red and blue foreground curves are the composite curves of the Revamped plant and the grey background curves are the composite curves of the Present-day plant.



Plant version	Total heating demand [MW]	Minimum external heating demand [MW]	Minimum external cooling demand [MW]
Present-day	52.4	23.1	25.5
Base case Revamped	52.4	24.1	25.9

Figure 2 Composite curves of the Base case plant compared to the composite curves of the Present-day plant. Pinch points are highlighted in the figure, total heating demand and minimum utility demands are shown in the table

An interesting effect of the distillation sequence revamp, which can be seen in Figure 2, is that the pinch temperature of the process shifts from 158 °C to 37 °C due to the revamp. As shown in the table in Figure 2 the Base case revamp leads to higher minimum heating and cooling demands than in the Present-day plant. The cause of both these observations are changes to the Amines plant process originating from the properties of the implemented new distillation sequence and from the way it needs to be operated.

The minimum utility demands obtained from the pinch study are measures of the external heating and cooling required in an Amines plant where direct heat exchange is performed between hot and cold streams to the largest possible extent. However, the layout of the heat exchanger network in the Present-day plant and the defined Base case Revamped plant does not allow for such a situation. The divergence of the actual utility demands from the minimum utility demands in these plants gives an indication of their level of heat integration. The sources of this divergence are referred to as pinch violations.

From studying the pinch violations in the Base case Revamped plant, areas where the heat integration of the revamped plant can be improved are identified. The potential for further heat integration (the sum of the pinch violations) in the Base case

Revamped plant amounts to 9.2 MW. Out of the pinch violations causing this potential, 93 % are connected to the pinch violation of cooling above the pinch. An intermediate hot water system, used for internal heat transfer in the Amines plant, is identified as the area with the largest potential for improvements. 4.9 MW of the heat absorbed in this hot water system is discharged to cooling water. If modifications suggested in this study can be performed, 141 ton/h of excess 90 °C water can be achieved from this system. If the hot water can be cooled by process heat sinks to 60 °C the waste of 4.9 MW of heat to cooling water can be eliminated. Further studies are however recommended to assess the improvement possibilities in this area.

The results and observations from the pinch study leads to the definition of three alternatives to the Base case revamp. These modifications to the Base case revamp include:

- enabling utilization of an excess of internally generated low pressure steam resulting from the revamp
- implementing a heat pump in one of the distillation towers of the plant
- combining these two alternatives to gain the benefits of both

The first of these alternatives targets increasing the use of low pressure steam in the plant, due to an excess of internally generated steam in the Base case Revamped plant. Modifications are suggested to shift the use of medium pressure steam to low pressure steam in some reboilers. By performing modifications to enable utilization of this excess steam, a pinch violation of 1.3 MW is eliminated.

In the second alternative, the possibility for implementing a heat pump in one of the distillation towers of the plant is recognized, as a result of the shift in pinch temperature. The temperature of the top stream from this tower is just below the pinch temperature in the Base case Revamped plant. By installing a mechanical vapor recompression heat pump the heat in this stream can be upgraded, so that it can be used to replace the hot utility use in the low temperature region above the pinch. In the suggested heat pump setup, the top stream from this tower is compressed to replace hot utility use in the reboilers of the same tower. This second alternative to the Base case revamp leads to a reduction of the external heating demand (and minimum heating demand) with 2.8 MW.

The possibility to combine these first two alternatives is investigated and confirmed as possible, in a third revamp alternative. There are no interferences between the two alternative process setups. Thus, the benefits from enabling utilization of excess low pressure steam and from implementing the described heat pump are additive.

The bar charts in Figure 3 summarize the results from the studies of the different revamp alternatives. The bars show the reduction in external heating demand for the revamp alternatives, relative to the demand in the Present-day plant. The relative change in electricity demand for the revamp alternatives is also shown in Figure 3.

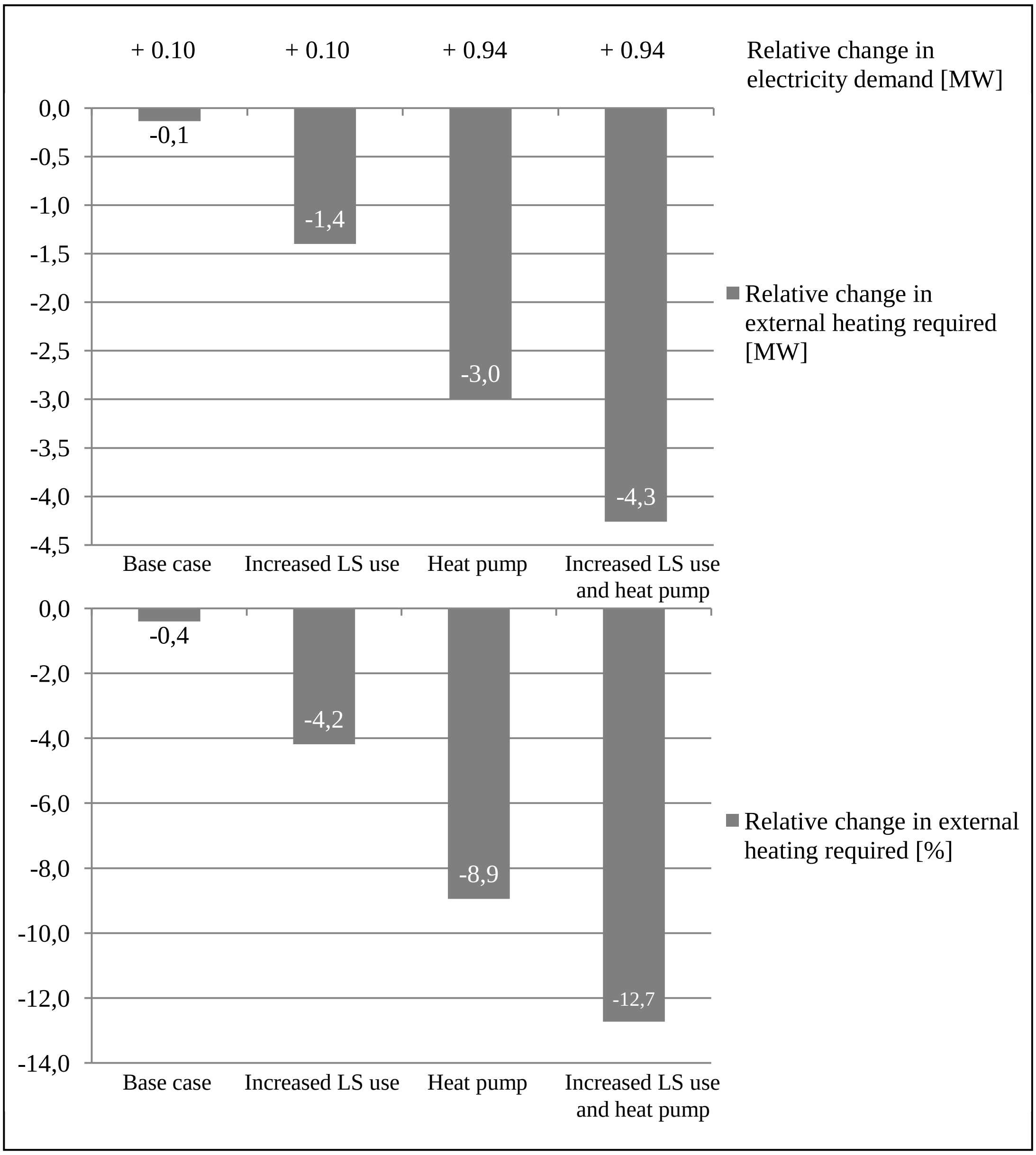


Figure 3 *Changes in electricity demand and external heating demand for the studied revamp alternatives relative to the Present-day plant demands*

As indicated in the bar charts of Figure 3, the external heating demand is reduced the most by implementing the third revamp alternative (Increased low pressure steam use and heat pump). This alternative leads to a reduction of the heat demand with 4.3 MW, corresponding to a 12.7 % reduction of the Present-day demand. However, as also indicated in Figure 3, the decreased heating requirement from installing a heat pump comes at the price of a higher electricity demand. In addition to the compressor electricity demand of 0.84 MW, the required compressor is a major economical investment.

The economical prospects of the proposed revamp are evaluated using steam and electricity costs obtained from recent revamp studies of the Amines plant. The evaluation focuses on the revamp with an increased low pressure steam use and the revamp with an increased low pressure steam use and a heat pump. For a suggested payback period of 3-5 years both alternatives show high enough profits to be considered as economically feasible. In addition to the economic benefits from the reduction in hot utility use, the increased product yield associated with the distillation sequence revamp contributes to this economic feasibility.

There are many aspects apart from the energy recovery prospects and economical prospects which need to be considered when deciding how to best perform the proposed revamp. The most important of these aspects concerns the intermediate hot water system in the plant. Due to the major pinch violation connected to this system, potential improvements of it need to be investigated before a decision is made. Such potential improvements include modifying the streams that are targeted in the heat pump alternative. There is in other words a risk that performing either of these revamps restricts the possibility to perform the other. Improvements to the hot water system could prove to be a more cost efficient way of achieving a hot utility reduction corresponding to the one associated with the heat pump, which has a high investment cost and electricity demand.

Revamps in line with the shift of medium pressure steam use to low pressure steam use are however necessary if the minimum heating demand is to be approached, due to the increased internal generation of low pressure steam in the Revamped Amines plant. This revamp has no risk of interfering with improvements of the hot water system. Thus, the final conclusion of this master's thesis study is that the revamp should be limited to this alternative until the possibilities of improving the intermediate hot water system have been further assessed.