Steam compressor for recycling of excess steam at chemical plant in the United Kingdom

Figure 1: One of the two steam compressors installed at chemical plant, United Kingdom.

Summary of demonstration case

At a chemical plant in North England, a completely new production line was installed, where excess steam from a reactor cooling is available with 5 bar(a). The first idea was to use it to generate some electricity by means of a steam turbine. But because of the low available pressure, only quite low electrical efficiency would have been resulting. Reconsidering the situation, the idea was born to instead recycle the complete heat content in the steam by compressing it to 19.5 bar(a), where it could be used again as process steam for other applications. For this purpose Spilling piston steam compressors were chosen. This type of compressor is characterized by good efficiencies and high flexibility, since they are operated with variable speed, enabling a variation from ~30 to 100 % steam flow rate.

For the given application, the compression from 5 to 19.5 bar(a) takes place in two stages. In a first stage from 5 to ~12 bar(a), and in a second stage then from ~12 to 19.5 bar(a). During compression the steam also becomes superheated, hence it is released on the discharge side at ~240 °C.

The Spilling steam compressor is a modular system with up 6 cylinders. For the full available excess steam flow rate of 16.5 t/h, two units were required like follows: a 6-cylinder unit (with four low pressure (LP) cylinders and two high pressure (HP) cylinders) with a capacity of 11 t/h, and a 3-cylinder unit (with two LP cylinders and one HP cylinder) with 5.5 t/h capacity. Before each compression stage, a certain quantity of condensate is injected into the steam, to avoid too high steam temperatures from the compression. By this, the steam flow rate on discharge side of the both units increases from 16.5 t/h to ~18 t/h altogether.

Comparing the heat load of the steam on the discharge side (~12 MW) with the nominal overall electrical power demand for both compressor units (~2.25 MW), a COP of ~5.3 is seen. Summarized, the nominal key figures for the two installed steam compressors are:

- 6-cylinder steam compressor + 3-cylinder steam compressor (each for double stage steam compression)
- Inlet steam: 5.0 bar(a) (saturated; ~152 °C)

- Outlet steam: 19.5 bar(a), (superheated with ~240 °C; sat. temp. ~211 °C)
- Steam flow rate (suction side): 11 t/h + 5.5 t/h
- Steam flow rate (discharge side): 12 t/h + 6 t/h
- El. power demand: 1.5 MW + 0.75 MW
- Heat load steam (discharge side)*: ~8 MW + 4.0 MW

*condensing heat + heat from condensate subcooling down to 105 °C.

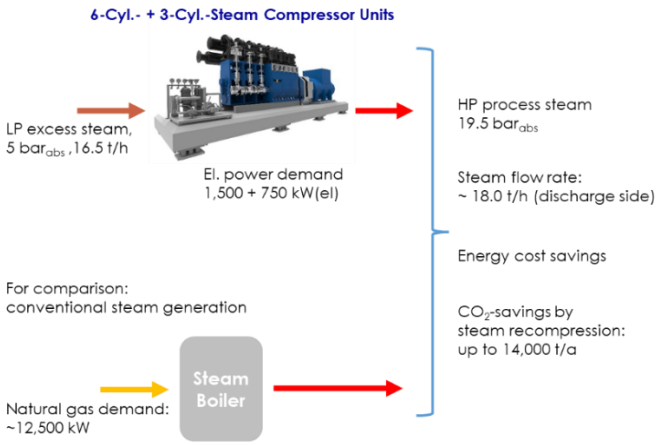

Figure 2: Steam parameters of steam compressor installation at chemical plant, United Kingdom.

Operating experiences

The installation of the new production line in the chemical plant took longer than originally planned. Therefore, the final commissioning of the steam compressors did not take place until summer 2021. During commissioning it was shown that the steam compressors have a better delivery rate than expected. They reach their nominal flow rates even at < 900 RPM (instead of 1,000 RPM full speed). Also their specific electrical power consumption is about 10 % lower compared to the nominal figures as described above, so in practice the resulting COP of the compressor units is even better (with COP_{real} > 5.8).

By recycling the 5.0 bar(a) excess steam via a steam compressor to 19.5 bar(a) process steam, compared to a conventional 19.5 bar(a) steam production with natural gas fired boiler, CO_2-savings of around 14,000 t/year are resulting. This is based on assumption with 7,500 full load operating hours, and CO_2-emissions of the UK electricity mix (year 2016) of ~0.281 kg/kWh.

FACTS ABOUT THE CASE

Installation year: 2018
Operating hours: n/a
Working fluid used: R-718 (water)
Compressor technology: Piston
System manufacturer: Spilling Technologies GmbH
Performance in design point:

- **Heat source:** 5.0 bar(a) steam with 152 °C
- **Heat sink:** 19.5 bar(a) steam, 240 °C (superheated), sat. temperature~ 211 °C
- **Heat supply capacity:** 12 MW
- **$COP_{Heating}$:** 5.3. This is based on condensing heat and heat from condensate subcooling to 105 °C in ratio to the compression power. The figure belongs to the contractual guaranteed max. electrical power demand of the compressor units, in practice it is even better with COP_{real} > 5.8. The electrical power demand and the heat load of the steam were validated by the customer during handover procedure.

Investment cost: 2,200,000 € without cost for integration.
Savings: unknown
Estimated annual CO_2 savings: 14,000 t/year

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All information were provided by the supplier without third-party validation. The infomation was provided as an indicative basis and may be different in final installations depending on application specific parameters.