

Thermocompressor Efficiency & Performance

Abstract

A thermocompressor is one of the simplest mechanical devices, yet presents one of the most challenging operational and design selections in a steam and condensate system. This complexity results in the misunderstandings, poor applications, and incorrect operation of a thermocompressor.

A thermocompressor's design should be coordinated with the design of all components comprising a steam and condensate system. A meaningful evaluation of a thermocompressor's performance must consider the full range of its operating conditions. Single point operating analysis leads to false conclusions and incorrect designs.

Paper Industry

Paper industry applications for thermocompressors are twofold: 1) Booster thermocompressors increase low pressure steam to a higher pressure; 2) Re-circulating thermocompressors recompress blowthrough steam from a dryer section or a Yankee dryer. The first application is somewhat unique and is not address in this paper.

Re-circulating thermocompressors installed in the paper industry are only one of many components in a dryer steam and condensate system. Other components are dryer cylinders, syphons, rotary joints, separator tanks, valves and various piping devices. Proper sizing of each of these components is necessary for optimum system performance. Additionally, it is necessary to develop an energy and mass flow balance for the various system operating conditions. In order of frequency, the performance difficulties or inefficiencies of thermocompressors are most frequently a result of:

- Poor instrumentation or control which causes poor performance and inaccurate measurements.
- A lack of accurate syphon performance data, improper syphon operation or syphon changes which lead to thermocompressors designs that do not match syphon performance.
- A change in a thermocompressor's operating conditions resulting from paper machine changes in product, furnish, added equipment, etc.
- The use of safety factors particularly for suction steam flows which leads to oversized thermocompressors. Proven techniques can be employed to accurately determine actual suction steam flows.

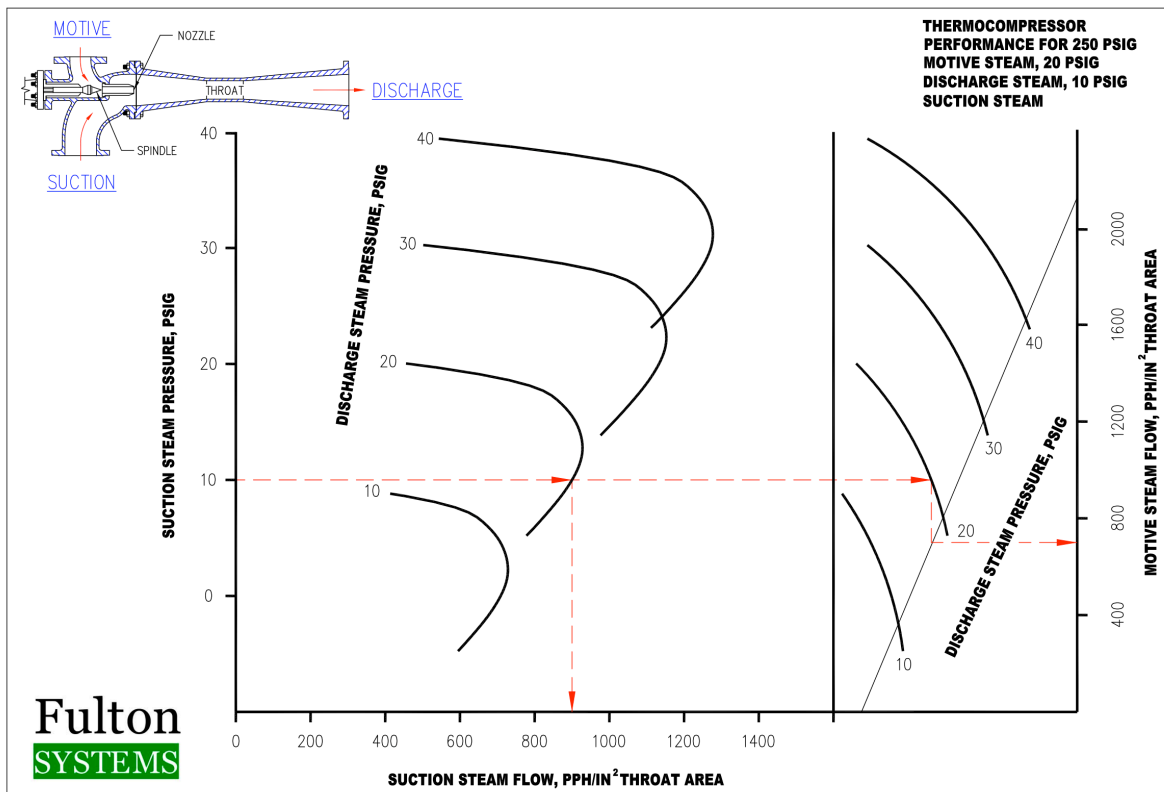
Obviously mills should address the first item, while suppliers should assist in the other three.

A Performance Picture.....

Referring to the following graph, which displays a couple of features:

- Graphs of performance of thermocompressors are not linear. For steam, thermodynamic evaluations involve several properties, e.g. pressure, temperature, enthalpy, mass flow and entropy. These properties are complex, interrelated and non-linear. Therefore curves, not straight lines, are required to graphically represent thermocompressor performance.
- To accurately represent the thermodynamic performance of a thermocompressor, at least two properties, e.g. pressures and mass flows, should be cross referenced.

The graph below simplifies the complex engineering sizing program for thermocompressors. The performance for a specific thermocompressor design is indicated by the dashed lines. In this example the motive pressure is 250 psig, the suction pressure is 10 psig and the discharge pressure is 20 psig. The dotted line indicates the path followed for the design. The suction pressure line intersects the discharge pressure line at a point that requires the diffuser throat to pass 925 pph/in² of suction steam. The size of the throat for a 3500 pph operating condition can be determined by dividing the actual suction steam flow by the unit capacity of 925 pph/in². The motive steam (follow the dashed line to the right vertical axis) is 670 pph/in² of throat area. Using the throat size, the required motive steam flow for 3500 pph of suction steam is 2535 pph. This yields an entrainment ratio (suction steam flow / motive steam flow) of 1.38.



It is important to understand that:

- This graph and example are based on thermodynamic principles, not thermocompressor geometry. The aspects of thermocompressor geometry that influence these results are the efficiencies of the two nozzles (one with a controlling spindle for the motive steam flow and the second in the diffuser throat) and the relationship of the motive steam nozzle exit to the diffuser throat. Nozzle efficiencies have evolved over the years as newer, better manufacturing techniques have been developed. Extensive research in the last 10 years has led to improvements in the overall efficiency of thermocompressors based on the nozzle-diffuser relationship. Theoretically, high efficiencies in the mid 90% are now achievable for both the nozzle and the unit.
- The intersection of the dashed line with the 20 psig discharge pressure curve is below the “knuckle” and “reverse bend” of this curve. As suction pressure increases above 10 psig on the 20 psig discharge curve, suction steam flows increase while motive steam flows decrease. Intuitively this makes sense since the difference in the suction and discharge pressures will decrease. There is a second point on the upper reverse bend curve that corresponds to the same suction flow as in our example. However, this second point is for a higher suction steam pressure. For this condition, less motive steam will be required. It is important to recognize that this phenomena resulting from the complex curve shapes exists and it can cause thermocompressor operating challenges.
- If the data point in our example is for the minimum operating condition, the throat design will likely be oversized for the maximum condition. This is a fact established by the thermodynamics inherent in the thermocompressor design. It constantly occurs since the minimum operating conditions usually determine the throat diameter. Years of steam and condensate system design experience is utilized to best optimize the thermocompressor performance for the maximum and minimum conditions. It is extremely rare that a single design will exactly meet both conditions. The wider the range of minimum and maximum operating conditions, the greater the compromise will be for the optimal thermocompressor design. For these reasons it is misleading to characterize thermocompressor performance by evaluating a single operating point.

Control Strategies

The management of thermocompressor performance is usually accomplished by one of three control strategies:

- Differential Pressure or DP. The DP across a dryer or dryer section is measured and the thermocompressor spindle is opened until the unit generates the controller set point DP.
- Blowthrough Steam or Flow control. The blowthrough steam of a dryer or dryer section is measured and the thermocompressor spindle is opened until the unit generates the controller set point.
- Pressure control. Commonly found on Yankee dryers, this strategy measures the Yankee operating steam pressure and modulates the thermocompressor spindle accordingly.

Although the above descriptions of these control strategies are somewhat straight forward, each has their advantages and disadvantages. All three can be fully implemented with standard controllers or DCS systems.

Recommendations

What should be part of the best practices for thermocompressor application and design? There are several recommendations:

1. Develop a production plan that shows the expected performance for the dryer or dryer section steam and condensate system. The plan should address the minimum and maximum production conditions.
2. Obtain explicit syphon performance curves and data. At a minimum, these curves and the supporting data should show the interdependent relationships of blowthrough steam, condensing load and differential pressure. They should agree with the production plan for the dryer section.
3. Request thermocompressor performance curves displaying the steam flows for different pressures including the expected minimum and maximum.

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