A Point of Order

At the planning stage, designers of refrigeration plants which serve mine cooling systems are often faced with the questions: how many chillers do I require for a certain duty? How can I optimally configure them for peak load and/or seasonal efficiency? For such ostensibly simple questions the answers, unfortunately, are not as straightforward. It turns out, a myriad of configurations exist, each with their merits and shortcomings and therefore every design should be fit for purpose. For the sake of this article we show the three most simplistic configurations in the accompanying diagram. Furthermore, one might consider fewer large capacity chillers as opposed to several smaller units due to first cost, whilst accepting the reduced level of redundancy.

Before unpacking the reasons behind these configurations, a basic understanding of efficiency as applied to refrigeration plants is necessary. Although several metrics are used, only the coefficient of performance (COP) will be considered here. Fundamentally, COP is the ratio of the desired cooling duty to the electrical input power. For example, a chiller with a COP of 4 should produce 4.0 MW_R of cooling with only 1.0 MW_E of power absorbed at the compressor motor(s). A point of confusion which often arises is whether the input power only refers to the compressor motor(s) or the entire system, as either are commonly used in performance tests. The latter also includes other equipment associated with the operation of the refrigeration plant such as water circulating pumps, cooling tower fans, reverse osmosis systems etc. Therefore, the *system* COP would always be lower than chiller COP.

To complicate matters further, chiller COP values are variable and influenced by, amongst others, the load (expressed as a percentage of the chiller capacity) and the evaporating/condensing temperatures. Generally, part load chiller COP's are slightly lower (in the order of -10%) when compared to the full load value. Both COPs improve significantly as the condensing temperature (cooling water side) decreases and/or the evaporator temperature (chilled water side) increases. The difference between these temperatures is termed the 'waterside lift', which is synonymous with the compressor head and ultimately the required work (power). Since chillers usually only operate at full load for short periods during high summer, it is important than part load efficiency is not overlooked.

Now armed with the above, we can get back to the question at hand. Chiller configurations are similar to electrical circuits in that series and parallel configurations are possible for each of the water circuits. Sometimes, it is even worthwhile having a combination of the two, i.e. multiple lead-lag (series) pairs arranged in parallel. The possibilities might seem endless, but some guiding principles are given below:

- At full load, a series evaporator configuration will have a higher COP than its parallel counterpart since the water temperature change across each heat exchanger would be smaller.
- Part load COPs will depend on the load and control philosophy. All else being equal, systems with more chillers would have a higher part load COP because as units are cycled off, the remaining machines will be operating at a higher load (on average).
- In similar configurations, large capacity chillers have a higher COP than smaller chillers, often due to increased heat exchanger and/or compressor efficiency unlocked at scale.
- Systems with fewer, large capacity chillers will cost less than those with smaller chillers. This is due to economies of scale not only from the chillers but also associated piping and electrical systems.

To illustrate, a hypothetical case study of a 12.0MW_R refrigeration plant where the relative differences in some key areas are qualitatively addressed in the table. It is evident that three chillers in series strike a reasonable balance between first cost, efficiency and redundancy. However, practical considerations such as the higher circuit pressure (read risk level and costlier pipes, valves & fittings) or the need for additional bypass loops to cater for unplanned maintenance events may determine otherwise. Furthermore, if the refrigeration plant were to be progressively phased in (as is often the case for ever deepening mines), the constant chilled water flowrate could involve an oversized initial bulk air cooler installation. A multi-facetted, wholistic approach is therefore required. BBE has the capability to undertake this work and ensure your next mine cooling project is not only a success but also efficient! Visit our contact us page and get in touch to find out more.