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The value of simplicity in design

If you can't draw a picture of it, you don't understand it.

If one rule relating to success in original engineering design efforts could be said to be the *most important* it would be: “keep it simple.” Two fundamental observations leading to this conclusion are:

- Inspection of numerous systems, say, five years after installation and start-up reveals that the vast majority are not being operated as intended by the designer. In many instances, this abortion of the designer's intent has resulted in less than satisfactory performance. As the investigation proceeds, it is found that the agent responsible for the operation has simply reduced the complexity of the system to his level of understanding.

- In the field of original engineering design, many of the concepts incorporated are a result of deficiencies revealed by previous designs that are subsequently resolved by *adding* a correction. As these corrections compound, system generation after system generation, they come to be accepted as the norm.

When a system designer sets out to define the parameters that he is attempting to satisfy by the design, each step in the process should be aimed at not only satisfying the parameters but also at satisfying them in such a manner that he fully understands how the system dynamics are going to respond to each operating mode and statepoint dictated by the load. Once the problem is addressed in this

manner, the designer will inevitably achieve a high level of simplicity (not a contradiction).

Consider this example

As an example, consider the design of a hot and/or chilled water system—a rather common subsystem in buildings or building complexes.

These are relatively simple in concept, consisting of a generator, expansion tank, circulator, load, and piping system. However, as designers attempt to satisfy various reduced load conditions and multiple modes of operation, such devices as load control valves, three-way mixing valves, secondary pumping, multiple expansion tanks, emergency system interconnections, system bypass valves (for constant chilled water flow), etc., are added, not to mention the inherent complexity resulting from sheer size and scope. As a result of this, there are an untold number of systems serving large building facilities and campuses today that have become so complex that thermal-hydraulic network analyses are virtually impossible to perform.

This degree of complexity must be avoided with deliberation by the designer. Although at first glance the response might be that simplicity cannot be achieved and the multitude of performance parameters still satisfied. There are, however, some rather fundamental rules that can be followed that will assist the designer in accomplishing this goal. For hy-

drone systems, these rules might be as follows.

Hydronic systems design rules

- If two or more systems are hydraulically interconnected (such as with campus systems or two-pipe heating/cooling systems), *never* have more than one expansion tank. The expansion tank, in addition to serving as an expansion volume for the liquid, is *the* constant pressure point of the system. If more than one such point is attempted, control of the system pressure is virtually impossible to predict under an infinite number of different dynamic response load conditions.

- When multiple pumping circuits are interconnected, such as with primary-secondary pumping, design for dynamic response isolation between the pumping systems. The secondary pump performance, for instance, should be virtually independent of the primary pump. With a little study, this independence can be achieved quite easily in most designs by the rigorous application of the “common pipe” principle.

- Try to achieve the design without the use of three-way mixing valves. Most control response requirements can be achieved with globe or “two-way” control valves. When three-way valves are used, it is easy to fall into the trap of unanticipated series pumping. Furthermore, the part load hydraulic performance of three-way valves is, to say the least, ill defined in practice.

- Consider secondary pumping of source devices such as boilers and chillers. Properly designed, this can be accomplished as economically as such alternatives as load bypass valves, chiller two-way valves, or load three-way valves, with more predictable results and reduced part load energy consumption.

- Draw a flow diagram of the entire system at the early stages of design and again after the design is complete. There is a philosophy in addressing technical problems: if you can’t draw a picture of it, you don’t understand it. The reverse is also generally true. The flow diagram (preferably in ladder diagram form) is a comprehensive picture or schematic of the thermal-hydraulic system. It enables the designer to achieve understandable simplicity and readily identify designed-in problems, serves as an aid to the installing agents in interpreting construction diagrams, and provides an invaluable tool in the ongoing operation and diagnostic servicing of system problems. The flow diagram, well developed, will immediately reveal the design philosophy of the system.

The hydronic system has been used as an example to illustrate the concept of designing for simplicity. This concept can and should be extended into each and every subsystem and component. If done successfully, system performance will be improved, and as a bonus benefit first cost will generally be reduced.