TAKING THE PHYSICAL APPROACH

TODAY, MODELING AIR FLOW usually implies using computational fluid dynamics software. But physical models still provide many advantages.

Power burners produce and deliver some of the largest controlled flames in the world. They are used to generate steam for process industries or power production, and they generally range in size from 30 million to more than 300 million Btu per hour on a single burner heat release basis.

To ensure stable, reliable operation, power burners require a proper fuel and air mixture—typically 19 parts air for every one part fuel. The delivery and control of air is aided by a component called a "windbox" that contains baffles or perforated plates for directing the flow. Baffles work better than plates (which are called a distribution grid) but require modeling to ensure they are placed to produce the optimal effect.

Today, when engineers hear the word "modeling" they expect to it to be done in a software simulation. But Zeeco, the combustion and environmental engineering company where I work, has found that physical modeling is a more accurate, efficient, and flexible method of testing and adjusting air flow in a closed system.

Given the sizes of typical industrial boilers, building a full-scale replica of the boiler to conduct airflow testing is not practical: Windboxes can be as much as 26 ft. wide and 8 ft. deep. So, Zeeco builds manageable scale models for ease of testing—typically 1:4 to 1:8 scale. Zeeco constructs the models from Plexiglas because it is readily available, easy to work with, inexpensive, and most importantly, transparent. The ability to observe the flow and baffle locations aids in finding the optimal solution.

When setting up a test in a physical model, the first trial for baffle size, quantity, and location is an estimation based on experience. A trial-and-error method is then undertaken to determine the optimal solution. Baffle locations or angles can be adjusted, for instance. Baffles can be added to correct a spin in the air flow, but doing so may disrupt the uniform outlet distribution. The iterative process is used to correct and engineer the mass flow through the system as a whole. Changing the location or orientation of a baffle in the model takes a matter of seconds and adding a new baffle takes a matter of minutes.

The process of observing a problem, changing baffles, and recording another data point typically takes 15 minutes or less.

As an example of the flexibility of physical modeling, during the commissioning of a particular job in Canada, the service technician observed a potential airflow problem with the flame. It appeared the combustion air was swirling upon exiting the burner. So, a paddle spinner was installed to test this theory. A video shot of the spinner turning during a cold flow test showed a clockwise spin. When the windbox was inspected to ensure the baffles were installed properly, it was noted the old windbox wall had warped over time, creating a gap between one of the walls and two of the baffles.

These findings were relayed back to a physical modeling team that had access to a model of the boiler system constructed during the design and engineering phase of the project. It took only a few minutes to move the baffles to the observed position in the damaged windbox and retest the flow. A video was taken of the model and, when placed side by side with the onsite video, the swirl of the spinners was observed to be identical.

Clearly, the problem had been correctly identified.

Next, the air flow model engineer adjusted the baffles. After a few iterations that took less than an hour, a solution involving placement of the baffles—and no significant system changes—was relayed back to installation site. The correction was implemented the same day it was discovered.

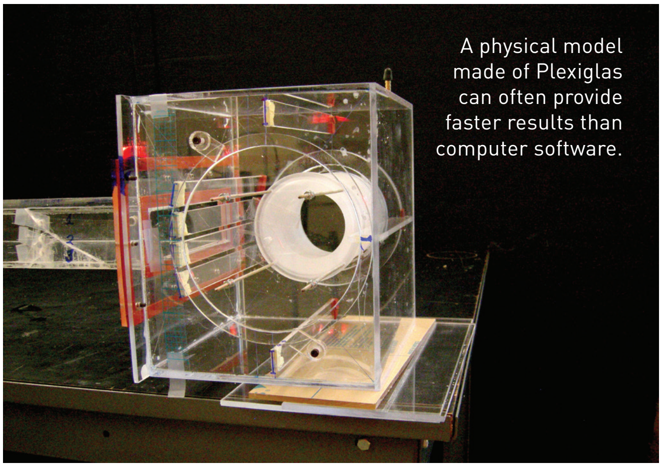
Solving this issue solely with a computerized model via computational fluid dynamics would have taken days or even weeks.

More important than the flexibility and efficiency of physical testing is the accuracy of the results. Zeeco has yet to experience an instance where the physical model did not accurately reflect the conditions in the field. On the other hand, CFD modeling may not accurately reflect actual conditions. Each simulation begins with a number of assumptions: inlet conditions, outlet conditions, boundary layers, and boundary conditions. These assumptions are required to utilize the mathematical equations.

Other assumptions are made to decrease the CFD model's size and run time. For example, a distribution grid is typically modeled as a plane of pressure drop as opposed to a porous metallic object that would affect flows in ways a simulated pressure drop would not. While these assumptions can often produce similar results to actual conditions, physical modeling makes significantly fewer assumptions, leading to inherently more reliable results.

In physical modeling, inlet and outlet conditions and boundaries are replicated and each piece is fabricated instead of assumed.

Finally, the main benefit of physical modeling is the finished result: the solution indicated by the model maps directly to the actual solution in the field. The final solution of a CFD model cannot be validated without the proof of physical data. Physical modeling skips the step of predicting what may potentially happen and directly models what is actually happening, providing a real-time analysis of the physical world. ME


A physical model made of Plexiglas can often provide faster results than computer software.

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