New Thermodynamic Theory Will Help Engineers 'Go With the Flow'

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"Constructal Law" may enable the designers of cars, planes, air conditioners and other devices to take a more scientific approach to a development process now based on trial and error

Friday, June 18, 2004 -- DURHAM, N.C. - A scientific paper that provides tools based on a new principle of thermodynamics, called "Constructal Law", may enable the designers of automobiles, jet planes, air conditioners and other devices to take a more scientific approach to a development process now based on trial and error.

Basically, Constructal Law provides such designers a method to minimize the resistance of flow throughout a system -- whether ocean currents or an air conditioner -- in an integrated way. A key advantage of Constructal Law, said its developers, is that it enables designers to systematically balance flow resistances in a complex system to arrive at the most efficient design.

European researchers already have begun applying Constructal Law in designs for heat exchangers, urban heating distribution networks and electronics cooling systems. Other researchers are applying the principle to explain natural processes such as the shape of animals or the circulation of ocean currents or atmospheric winds.

The latest developments of Constructal Law were described in an article in the July 2004 issue of the International Journal of Heat and Mass Transfer by the law's principal developer, Adrian Bejan, a

thermodynamics expert and mechanical engineering professor at Duke's Pratt School of Engineering, and Sylvie Lorente, a civil engineering professor from the Laboratory of Materials and Durability of Constructions at the National Institute of Applied Sciences in Toulouse, France.

The article provides analytical and graphical tools for applying Constructal Law to better explain how air, water and other substances flow through designs ranging from animals to machines.

The two researchers said Constructal Law could improve design throughout engineering and enhance scientific understanding of basic natural processes involving flow. "Constructal Law provides designers with a sense of reference, helping them to understand the efficiency performance limits," said Bejan. "A decision to change the design to make it more efficient then becomes an informed decision about resources and money. Constructal Law is a mental vision of the origin and evolution of design. Design includes configuration, architecture, geometry, and drawings," he said.

"Resistances cannot be minimized individually and indiscriminately, because of constraints: space is limited, streams must connect components, and components must fit inside the greater system," said Bejan. "Resistances compete against each other. The route to improvements in global performance is by balancing the reductions in the competing resistances."

The idea that flow systems need to decrease flow resistance to improve performance seems intuitively obvious, but has not been effectively incorporated into the design process, according to Bejan. Traditionally, engineers measure a machine's input and output to calculate its overall efficiency, he said. If the machine is not efficient enough, a designer typically goes back to the drawing board to create a different design, an

approach that provides inadequate insight into how to actually improve the machine.

"Design today is still largely an artistic endeavor, with designers literally starting with a blank page and the burden of choosing from infinite possibilities for structuring their machine," said Bejan. "Constructal Law's contribution is that it drives home the universality of flow access maximization, and makes it possible to use that information to deduce and improve engineering design." The theory's ability to explain both natural and engineered systems supports its validity, he said.

In their new paper, Bejan and Lorente provide graphical tools to help researchers apply Constructal Law principles to analyze a system's configuration and performance. Designs are characterized by performance and configuration. The freedom to change the configuration is good for enhancing performance. The most efficient systems balance the global objectives of the flow system with the global restrictions of the system's environment, which the authors call an "optimal distribution of imperfection."

According to Bejan, Constructal Law also reveals the limits on the efficiency of a system, revealing the point of diminishing returns beyond which additional changes to the system's design will not improve performance significantly.

The original news release is available here.