The three designs use the same amount of thermal insulation. The k and $\dot{m}_0$ values are such that the N_0 value based on the L_0 scale of the n = 16 case is N_0 = 0.01. The dimensionless volume

$$\tilde{V}_{16} = V_{16}/(\pi L_0 r_{i0}^2)$$

where V_{16} is the total volume of the insulation (the same in all three designs), and L_0 and r_{i0} are the length and radius of the elemental pipes in the n = 16 design. Fig 7 shows that the temperature of the water received by the end-user increases as the complexity of the structure (n) increases. A characteristic of the one-by one growth is the memory that is demented into each design. What was built prior to the attachment of the newest user is retained. This characteristic is found in other flow-shaped flows in nature, civil engineering and society.

Conclusion

The chief conclusion is that the use of geometric form (shape, structure) is an effective route to achieving high levels of global performance under constraints. The brute force approach of delivering hot water by using large amounts of insulation and flow rates (small N) is not economical. Much faster progress toward the goal of global performance maximisation can be made by recognising and treating the geometric configuration of the flow system as the main unknown of the problem[1].

The constructal design method[1] illustrated by the work reviewed in this paper can be extended to several related applications. First, networks for the distribution of chilled water require similar tradeoffs for the distribution of insulation, pipe diameters and pipe links over a territory populated by users. Second, when the territory is populated by a few large-volume users, the uniform distribution of users employed in this paper must be replaced by a few discrete nodes of consumption. Third, there are many civil engineering applications in which the nodes of consumption are fixed points on the territory, not freely moving points as in Fig 6. Networks where some of the nodes of consumption are fixed could be approached based on the same method in future studies.

The demonstrated effectiveness of the geometric optimisation method is relevant to the optimisation of practically every distributed scheme for heating or cooling a specified area or volume. An example from the cooling of electronics is a disc-shaped area that generates heat uniformly: this can be cooled most effectively by covering the area with tree-shaped inserts of high conductivity material[11].

Acknowledgement

This work was supported by a grant from the National Science Foundation. Mr W Wechsatol also acknowledges the support received from King Mongkut's University of Technology Thonburi (KMUTT), Thailand.

References

1. *Bejan, A, 2000, Shape and Structure, from Engineering to Nature, Cambridge University Press, Cambridge, UK.*
2. *Padet, J, 1991, Fluides en Écoulement. Méthodes et Modèles, Masson, Paris.*
3. *Dupont, A, 1977, Hydraulique Urbaine, Ouvrages de Transport, Elévation et Distribution, Eyrolles, Paris.*
4. *Nonclercq, P, 1982, Hydraulique Urbaine Appliquée, CEBEDOC, Liège.*
5. *Barreau, A, and Moret-Bailly, J, 1977, "Présentation de Deux Méthodes d'Optimisation de Réseaux de Transport d'Eau Chaude à Grande Distance," Entropie, Vol. 75, pp. 21-28.*
6. *Moran, MJ and Sciubba, E, 1994, "Exergetic Analysis: Principles and Practice," J Eng Gas Turbine Power, Vol. 116, pp. 285-290.*
7. *Wechsatol, W, Lorente, S and Bejan, A, 2001, "Tree-Shaped Insulated Designs for the Uniform Distribution of Hot Water over an Area," Int. J Heat Mass Transfer, Vol. 44, pp. 3111-3123.*
8. *Wechsatol, W, Lorente, S and Bejan A, 2002, "Development of Tree-Shaped Flows by Adding New Users to Existing Networks of Hot Water Pipes", Int. J Heat Mass Transfer, Vol. 45, pp.723-733.*
9. *Lorente S, Wechsatol W, Bejan A. "Tree-shaped flow structures designed by minimising path lengths", Int. J Heat Mass Transfer, 2002, Vol. 45(16), pp. 3299-3312.*
10. *Bejan, A, Rocha, LAO and Lorente, S, 2000, "Thermodynamic Optimisation of Geometry: T- and Y-Shaped Constructs of Fluid Streams," Int. J Therm Sci, Vol. 39, pp. 949-960.*
11. *Rocha, LAO, Lorente, S, Bejan, A, 2002, "Constructal Design for Cooling a Disc-Shaped Area by Conduction", Int. J Heat Mass Transfer, Vol. 45, pp. 1643-1652.*

Fig Captions

Fig 1: String of users supplied by a single hot stream.
Fig 2: Sequence of square-shaped constructs.
Fig 3: Comparison between the maximised water temperatures delivered to the farthest users in Fig 1 and Fig 2.
Fig 4: Sequence of constructs obtained by pairing.
Fig 5: Comparison between the end-user temperatures of the constructs of Figs. 2 and 4.
Fig 6: Growing hot-water distribution network constructed by adding one new user at a time, and placing it in the best location.
Fig 7: Comparison between the one-by-one designs of Fig 6, showing how the performance improves as the complexity (n) increases.